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THE SEPTEMBER SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

THE INTERDEPENDENCE OF SCIENCE AND MEDICINE. THE LATE LORD LISTER 193
PROGRESS AND THE SCIENCES. DR. WALTER W. LUCASSE 213
JAN JACOBZ SWAMMERDAM. DR. HARRY B. WEISS 220
NIGERIA. PROFESSOR A. S. PEARSE 228
THE EVOLUTION OF THE PARENT. DR. NATHAN MILLER 240
ARSENIC EATERS. PROFESSOR NORMAN J. HARRAR 246
METHODS IN THE STUDY OF DOMESTICATIONS. DR. BERTHOLD LAUFER 251
AQUICULTURE AND THE FUTURE OF THE WATERS. PROFESSOR R. E. COKER 256
VOCAL THERMOMETERS. BERT E. HOLMES 261
AMERICAN WILD HORSES. DR. JAMES W. GIDLEY 265
IRON CRYSTALS. DR. L. W. MCKEEHAN 272
COMBINATION, UNIT AND PEACE. PROFESSOR EZRA BOWEN 277
THE PROGRESS OF SCIENCE:
Fluid Fuel; Protection from Poison Ivy; Mutations caused by X-rays; Hafnium 281

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with comments by the publishers

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THE SCIENTIFIC MONTHLY

SEPTEMBER, 1927

THE INTERDEPENDENCE OF SCIENCE AND MEDICINE[1]

By the Late LORD LISTER

I HAVE first to express my deep sense of gratitude for the great honor conferred upon me by my election to the high office which I occupy to-day. It came upon me as a great surprise. The engrossing claims of surgery have prevented me for many years from attending the meetings of the association, which excludes from her sections medicine in all its branches. This severance of the art of healing from the work of the association was right and indeed inevitable. Not that medicine has little in common with science. The surgeon never performs an operation without the aid of anatomy and physiology; and in what is often the most difficult part of his duty, the selection of the right course to follow, he, like the physician, is guided by pathology, the science of the nature of disease, which, though very difficult from the complexity of its subject-matter, has made during the last half-century astonishing progress; so that the practice of medicine in every department is becoming more and more based on science as distinguished from empiricism. I propose on the present occasion to bring before you some illustrations of the interdependence of science and the healing art; and the first that I will take is perhaps the most astonishing of all results of purely physical inquiry—the discovery of the Röntgen rays, so called after the man who first clearly revealed them to the world. Mysterious as they still are, there is one of their properties which we can all appreciate—their power of passing through substances opaque to ordinary light. There seems to be no relation whatever between transparency in the common sense of the term and penetrability to these emanations. The glasses of a pair of spectacles may arrest them while their wooden and leather case allows them to pass almost unchecked. Yet they produce, whether directly or indirectly, the same effects as light upon a photographic plate. As a general rule, the denser any object is, the greater obstacle does it oppose to the rays. Hence, as bone is denser than flesh, if the hand or other part of the body is placed above the sensitive film enclosed in a case of wood or other light material at a suitable distance from the source of the rays, while they pass with the utmost facility through the uncovered parts of the lid of the box and powerfully affect the plate beneath, they are arrested to a large extent by the bones, so that the plate is little acted upon in the parts opposite to them, while the portions corresponding to the muscles and other soft parts are influenced in an intermediate degree. Thus a picture is obtained in which the bones stand out in sharp relief among the flesh, and

[1] Address by the President of the British Association for the Advancement of Science, given at the Liverpool meeting of 1896.

anything abnormal in their shape or position is clearly displayed.

I need hardly point out what important aid this must give to the surgeon. As an instance, I may mention a case which occurred in the practice of Mr. Howard Marsh. He was called to see a severe injury of the elbow, in which the swelling was so great as to make it impossible for him by ordinary means of examination to decide whether he had to deal with a fracture or a dislocation. If it were the latter, a cure would be effected by the exercise of violence, which would be not only useless, but most injurious, if a bone was broken. By the aid of the Röntgen rays a photograph was taken in which the bone of the upper arm was clearly seen displaced forwards on those of the forearm. The diagnosis being thus established, Mr. Marsh proceeded to reduce the dislocation; and his success was proved by another photograph which showed the bones in their natural relative position.

The common metals, such as lead, iron and copper, being still denser than the osseous structures, these rays can show a bullet embedded in a bone or a needle lodged about a joint. At the last conversazione of the Royal Society a picture produced by the new photography displayed with perfect distinctness through the bony framework of the chest a halfpenny low down in a boy's gullet. It had been there for six months, causing uneasiness at the pit of the stomach during swallowing; but whether the coin really remained impacted, or, if so, what was its position, was entirely uncertain till the Röntgen rays revealed it. Dr. Macintyre, of Glasgow, who was the photographer, informs me that when the presence of the halfpenny had been thus demonstrated, the surgeon in charge of the case made an attempt to extract it, and although this was not successful in its immediate object it had the effect of dislodging the coin; for a subsequent photograph by Dr. Macintyre not only showed that it had disappeared from the gullet, but also thanks to the wonderful penetrating power which the rays had acquired in his hands, proved that it had not lodged further down in the alimentary passage. The boy has since completely recovered.

The Röntgen rays cause certain chemical compounds to fluoresce, and emit a faint light plainly visible in the dark; and if they are made to fall upon a translucent screen impregnated with such a salt, it becomes beautifully illuminated. If a part of the human body is interposed between the screen and the source of the rays, the bones and other structures are thrown in shadow upon it, and thus a diagnosis can be made without the delay involved in taking a photograph. It was in fact in this way that Dr. Macintyre first detected the coin in the boy's gullet. Mr. Herbert Jackson, of King's College, London, early distinguished himself in this branch of the subject. There is no reason to suppose that the limits of the capabilities of the rays in this way have yet been reached. By virtue of the greater density of the heart than the adjacent lungs, with their contained air, the form and dimensions of that organ in the living body may be displayed on the fluorescent screen, and even its movements have been lately seen by several different observers.

Such important applications of the new rays to medical practice have strongly attracted the interest of the public to them, and I venture to think that they have even served to stimulate the investigations of physicists. The eminent professor of physics in the University College of this city (Professor Lodge) was one of the first to make such practical applications, and I was able to show to the Royal Society at a very early period a photograph, which he had the kindness to send me, of a bullet embedded in the hand. His interest in the medical aspect of the subject remains unabated, and at the same time he has

been one of the most distinguished investigators of its purely physical side.

There is another way in which the Röntgen rays connect themselves with physiology, and may possibly influence medicine. It is found that if the skin is long exposed to their action it becomes very much irritated, affected with a sort of aggravated sunburning. This suggests the idea that the transmission of the rays through the human body may be not altogether a matter of indifference to internal organs, but may, by long-continued action, produce, according to the condition of the part concerned, injurious irritation of salutary stimulation.

This is the jubilee of anesthesia in surgery. That priceless blessing to mankind came from America. It had, indeed, been foreshadowed in the first year of this century by Humphry Davy, who, having found a toothache from which he was suffering relieved as he inhaled laughing gas (nitrous oxide), threw out the suggestion that it might perhaps be used for preventing pain in surgical operations. But it was not till, on September 30, 1846, Dr. W. T. G. Morton, of Boston, after a series of experiments upon himself and the lower animals, extracted a tooth painlessly from a patient whom he had caused to inhale the vapor of sulphuric ether, that the idea was fully realized. He soon afterwards publicly exhibited his method at the Massachusetts General Hospital, and after that event the great discovery spread rapidly over the civilized world. I witnessed the first operation in England under ether. It was performed by Robert Liston in University College Hospital, and it was a complete success. Soon afterwards I saw the same great surgeon amputate the thigh as painlessly, with less complicated anesthetic apparatus, by aid of another agent, chloroform, which was being powerfully advocated as a substitute for ether by Dr. (afterwards Sir James Y.) Simpson, who also had the great merit of showing that confinements could be conducted painlessly, yet safely, under its influence. These two agents still hold the field as general anesthetics for protracted operations, although the gas originally suggested by Davy, in consequence of its rapid action and other advantages, has taken their place in short operations, such as tooth extraction. In the birthplace of anesthesia ether has always maintained its ground; but in Europe it was to a large extent displaced by chloroform till recently, when many have returned to ether, under the idea that, though less convenient, it is safer. For my own part, I believe that chloroform, if carefully administered on right principles, is, on the average, the safer agent of the two.

The discovery of anesthesia inaugurated a new era in surgery. Not only was the pain of operations abolished, but the serious and sometimes mortal shock which they occasioned to the system was averted, while the patient was saved the terrible ordeal of preparing to endure them. At the same time the field of surgery became widely extended, since many procedures, in themselves desirable, but before impossible from the protracted agony they would occasion, became matters of routine practice. Nor have I by any means exhausted the list of the benefits conferred by this discovery.

Anesthesia in surgery has been from the first to last a gift of science. Nitrous oxide, sulphuric ether and chloroform are all artificial products of chemistry, their employment as anesthetics was the result of scientific investigation, and their administration, far from being, like the giving of a dose of medicine, a matter of rule of thumb, imperatively demands the vigilant exercise of physiological and pathological knowledge.

While rendering such signal service to surgery, anesthetics have thrown light upon biology generally. It has been found that they exert their soporific influence not only upon vertebrata, but upon animals so remote in structure from

man as bees and other insects. Even the functions of vegetables are suspended by their agency. They thus afford strong confirmation of the great generalization that living matter is of the same essential nature wherever it is met with on this planet, whether in the animal or vegetable kingdom. Anesthetics have also, in ways to which I need not here refer, powerfully promoted the progress of physiology and pathology.

My next illustration may be taken from the work of Pasteur on fermentation. The prevailing opinion regarding this class of phenomena when they first engaged his attention was that they were occasioned primarily by the oxygen of the air acting upon unstable animal or vegetable products, which, breaking up under its influence, communicated disturbance to other organic materials in their vicinity, and thus led to their decomposition. Cagniard-Latour had, indeed, shown several years before that yeast consists essentially of the cells of a microscopic fungus which grows as the sweetwort ferments; and he had attributed the breaking up of the sugar into alcohol and carbonic acid to the growth of the micro-organism. In Germany Schwann, who independently discovered the yeast plant, had published very striking experiments in support of analogous ideas regarding the putrefaction of meat. Such views had also found other advocates, but they had become utterly discredited, largely through the great authority of Liebig, who bitterly opposed them.

Pasteur, having been appointed as a young man dean of the faculty of sciences in the University of Lille, a town where the products of alcoholic fermentation were staple articles of manufacture, determined to study that process thoroughly; and, as a result, he became firmly convinced of the correctness of Cagniard-Latour's views regarding it. In the case of other fermentations, however, nothing fairly comparable to the formation of yeast had till then been observed. This was now done by Pasteur for that fermentation in which sugar is resolved into lactic acid. This lactic fermentation was at that time brought about by adding some animal substance, such as fibrin, to a solution of sugar, together with chalk that should combine with the acid as it was formed. Pasteur saw, what had never before been noticed, that a fine gray deposit was formed, differing little in appearance from the decomposing fibrin, but steadily increasing as the fermentation proceeded. Struck by the analogy presented by the increasing deposit to the growth of yeast in sweetwort, he examined it with the microscope, and found it to consist of minute particles of uniform size. Pasteur was not a biologist, but although these particles were of extreme minuteness in comparison with the constituents of the yeast plant, he felt convinced that they were of an analogous nature, the cells of a tiny microscopic fungus. This he regarded as the essential ferment, the fibrin or other so-called ferment serving, as he believed, merely the purpose of supplying to the growing plant certain chemical ingredients not contained in the sugar, but essential to its nutrition. And the correctness of this view he confirmed in a very striking manner, by doing away with the fibrin or other animal material altogether, and substituting for it mineral salts containing the requisite chemical elements. A trace of the gray deposit being applied to a solution of sugar containing these salts, in addition to the chalk, a brisker lactic fermentation ensued than could be procured in the ordinary way.

I have referred to this research in some detail because it illustrates Pasteur's acuteness as an observer and his ingenuity in experiment, as well as his almost intuitive perception of truth.

A series of other beautiful investigations followed, clearly proving that all true fermentations, including putrefac-

tion, are caused by the growth of micro-organisms.

It was natural that Pasteur should desire to know how the microbes which he showed to be the essential causes of the various fermentations took their origin. It was at that period a prevalent notion, even among many eminent naturalists, that such humble and minute beings originated *de novo* in decomposing organic substances; the doctrine of spontaneous generation, which had been chased successively from various positions which it once occupied among creatures visible to the naked eye, having taken its last refuge where the objects of study were of such minuteness that their habits and history were correspondingly difficult to trace. Here again Pasteur at once saw, as if by instinct, on which side the truth lay; and perceiving its immense importance, he threw himself with ardor into its demonstration. I may describe briefly one class of experiments which he performed with this object. He charged a series of narrow-necked glass flasks with a decoction of yeast, a liquid peculiarly liable to alteration on exposure to the air. Having boiled the liquid in each flask, to kill any living germs it might contain, he sealed its neck with a blowpipe during ebullition; after which the flask being allowed to cool, the stream within it condensed, leaving a vacuum above the liquid. If, then, the neck of the flask were broken in any locality, the air at that particular place would rush in to fill the vacuum, carrying with it any living microbes that might be floating in it. The neck of the flask having been again sealed, any germs so introduced would in due time manifest their presence by developing in the clear liquid. When any of such a series of flasks were opened and re-sealed in an inhabited room, or under the trees of a forest, multitudes of minute living forms made their appearance in them; but if this was done in a cellar long unused, where the suspended organisms, like other dust, might be expected to have all fallen to the ground, the decoction remained perfectly clear and unaltered. The oxygen and other gaseous constituents of the atmosphere were thus shown to be of themselves incapable of inducing any organic development in yeast water.

Such is a sample of the many well-devised experiments by which he carried to most minds the conviction that, as he expressed it, "*la génération spontanée est une chimère*," and that the humblest and minutest living organisms can only originate by parentage from beings like themselves.

Pasteur pointed out the enormous importance of these humble organisms in the economy of nature. It is by their agency that the dead bodies of plants and animals are resolved into simpler compounds fitted for assimilation by new living forms. Without their aid the world would be, as Pasteur expresses it, *encombré de cadavres*. They are essential not only to our well-being, but to our very existence. Similar microbes must have discharged the same necessary function of removing refuse and providing food for successive generations of plants and animals during the past periods of the world's history; and it is interesting to think that organisms as simple as can well be conceived to have existed when life first appeared upon our globe have, in all probability, propagated the same lowly but most useful offspring during the ages of geological time.

Pasteur's labors on fermentation have had a very important influence upon surgery. I have been often asked to speak on my share in this matter before a public audience; but I have hitherto refused to do so, partly because the details are so entirely technical, but chiefly because I have felt an invincible repugnance to what might seem to savor of self-advertisement. The latter objection now no longer exists, since advancing years have indicated that it is right for me to leave

to younger men the practice of my dearly loved profession. And it will perhaps be expected that, if I can make myself intelligible, I should say something upon the subject on the present occasion.

Nothing was formerly more striking in surgical experience than the difference in the behavior of injuries according to whether the skin was implicated or not. Thus, if the bones of the leg were broken and the skin remained intact, the surgeon applied the necessary apparatus without any other anxiety than that of maintaining a good position of the fragments, although the internal injury to bones and soft parts might be very severe. If, on the other hand, a wound of the skin was present, communicating with the broken bones, although the damage might be in other respects comparatively slight, the compound fracture, as it was termed, was one of the most dangerous accidents that could happen. Mr. Syme, who was, I believe, the safest surgeon of his time, once told me that he was inclined to think that it would be, on the whole, better if all compound fractures of the leg were subjected to amputation, without any attempt to save the limb. What was the cause of this astonishing difference? It was clearly in some way due to the exposure of the injured parts to the external world. One obvious effect of such exposure was indicated by the odor of the discharge, which showed that the blood in the wound had undergone putrefactive change by which the bland nutrient liquid had been converted into highly irritating and poisonous substances. I have seen a man with compound fracture of the leg die within two days of the accident, as plainly poisoned by the products of putrefaction as if he had taken a fatal dose of some potent toxic drug.

An external wound of the soft parts might be healed in one of two ways. If its surfaces were clean cut, and could be brought into accurate apposition, it might unite rapidly and painlessly "by the first intention." This, however, was exceptional. Too often the surgeon's efforts to obtain primary union were frustrated, the wound inflamed and the retentive stitches had to be removed, allowing it to gape; and then, as if it had been left open from the first, healing had to be effected in the other way which it is necessary for me briefly to describe. An exposed raw surface became covered in the first instance with a layer of clotted blood or certain of its constituents, which invariably putrefied; and the irritation of the sensitive tissues by the putrid products appeared to me to account sufficiently for the inflammation which always occurred in and around an open wound during the three or four days which elapsed before what were termed "granulations" had been produced. These constituted a coarsely granular coating of very imperfect or embryonic structure, destitute of sensory nerves and prone to throw off matter or pus, rather than absorb, as freshly divided tissues do, the products of putrefaction. The granulations thus formed a beautiful living plaster, which protected the sensitive parts beneath from irritation, and the system generally from poisoning and consequent febrile disturbance. The granulations had other useful properties, of which I may mention their tendency to shrink as they grew, thus gradually reducing the dimensions of the sore. Meanwhile, another cause of its diminution was in operation. The cells of the epidermis, or scarfskin of the cutaneous margins, were perpetually producing a crop of young cells of similar nature, which gradually spread over the granulations till they covered them entirely, and a complete cicatrix or scar was the result. Such was the other mode of healing that, by granulation and cicatrization, a process which, when it proceeded unchecked to its completion, commanded our profound admiration. It was, however, essentially tedious compared with

primary union, while, as we have seen, it was always preceded by more or less inflammation and fever, sometimes very serious in their effects. It was also liable to unforeseen interruptions. The sore might become larger instead of smaller, cicatrization giving place to ulceration in one of its various forms, or even to the frightful destruction of tissue which, from the circumstance that it was most frequently met with in hospitals, was termed hospital gangrene. Other serious and often fatal complications might arise, which the surgeon could only regard as untoward accidents and over which he had no efficient control.

It will be readily understood from the above description that the inflammation which so often frustrated the surgeon's endeavors after primary union was, in my opinion, essentially due to decomposition of blood within the wound.

These and many other considerations had long impressed me with the greatness of the evil of putrefaction in surgery. I had done my best to mitigate it by scrupulous ordinary cleanliness and the use of various deodorant lotions. But to prevent it altogether appeared hopeless while we believed with Liebig that its primary cause was the atmospheric oxygen which, in accordance with the researches of Graham, could not fail to be perpetually diffused through the porous dressings which were used to absorb the blood discharged from the wound. But when Pasteur had shown that putrefaction was a fermentation caused by the growth of microbes, and that these could not arise *de novo* in the decomposable substance, the problem assumed a more hopeful aspect. If the wound could be treated with some substance which, without doing too serious mischief to the human tissues, would kill the microbes already contained in it and prevent the future access of others in the living state, putrefaction might be prevented, however freely the air with its oxygen might enter. I had heard of carbolic acid as having a remarkable deodorizing effect upon sewage, and having obtained from my colleague, Dr. Anderson, professor of chemistry in the University of Glasgow, a sample which he had of this product, then little more than a chemical curiosity in Scotland, I determined to try it in compound fractures. Applying it undiluted to the wound, with an arrangement for its occasional renewal, I had the joy of seeing these formidable injuries follow the same safe and tranquil course as simple fractures, in which the skin remains unbroken.

At the same time we had the intense interest of observing in open wounds what had previously been hidden from human view—the manner in which subcutaneous injuries are repaired. Of special interest was the process by which portions of tissue killed by the violence of the accident were disposed of, as contrasted with what had till then been invariably witnessed. Dead parts had been always seen to be gradually separated from the living by an inflammatory process and thrown off as sloughs. But when protected by the antiseptic dressing from becoming putrid and therefore irritating, a structure deprived of its life caused no disturbance in its vicinity; and on the contrary, being of a nutritious nature, it served as pabulum for the growing elements of the neighboring living structures, and these became in due time entirely substituted for it. Even dead bone was seen to be thus replaced by living osseous tissue.

This suggested the idea of using threads of dead animal tissue for tying blood vessels; and this was realized by means of catgut, which is made from the intestine of the sheep. If deprived of living microbes, and otherwise properly prepared, catgut answers its purpose completely; the knot holding securely, while the ligature around the vessel becomes gradually absorbed and replaced by a ring of living tissue. The threads,

instead of being left long as before, could now be cut short, and the tedious process of separation of the ligature, with its attendant serious danger of bleeding, was avoided.

Undiluted carbolic acid is a powerful caustic; and although it might be employed in compound fracture, where some loss of tissue was of little moment in comparison with the tremendous danger to be averted, it was altogether unsuitable for wounds made by the surgeon. It soon appeared, however, that the acid would answer the purpose aimed at, though used in diluted forms devoid of caustic action, and therefore applicable to operative surgery. According to our then-existing knowledge, two essential points had to be aimed at: to conduct the operation so that on its completion the wound should contain no living microbes; and to apply a dressing capable of preventing the access of other living organisms till the time should have arrived for changing it.

Carbolic acid lent itself well to both these objects. Our experience with this agent brought out what was, I believe, a new principle in pharmacology—namely, that the energy of action of any substance upon the human tissues depends not only upon the proportion in which it is contained in the material used as a vehicle for its administration, but also upon the degree of tenacity with which it is held by its solvent. Water dissolves carbolic acid sparingly and holds it extremely lightly, leaving it free to act energetically on other things for which it has greater affinity, while various organic substances absorb it greedily and hold it tenaciously. Hence its watery solution seemed admirably suited for a detergent lotion to be used during the operation for destroying any microbes that might fall upon the wound, and for purifying the surrounding skin and also the surgeon's hands and instruments. For the last-named purpose it had the further advantage that it did not act on steel.

For an external dressing the watery solution was not adapted, as it soon lost the acid it contained, and was irritating while it lasted. For this purpose some organic substances were found to answer well. Large proportions of the acid could be blended with them in so bland a form as to be unirritating; and such mixtures, while perpetually giving off enough of the volatile salt to prevent organic development in the discharges that flowed past them, served as a reliable store of the antiseptic for days together.

The appliances which I first used for carrying out the antiseptic principle were both rude and needlessly complicated. The years that have since passed have witnessed great improvements in both respects. Of the various materials which have been employed by myself and others, and their modes of application, I need say nothing except to express my belief, as a matter of long experience, that carbolic acid, by virtue of its powerful affinity for the epidermis and oily matters associated with it, and also its great penetrating power, is still the best agent at our disposal for purifying the skin around the wound. But I must say a few words regarding a most important simplification of our procedure. Pasteur, as we have seen, had shown that the air of every inhabited room teems with microbes; and for a long time I employed various more or less elaborate precautions against the living atmospheric dust, not doubting that, as all wounds except the few which healed completely by the first intention underwent putrefactive fermentation, the blood must be a peculiarly favorable soil for the growth of putrefactive microbes. But I afterwards learnt that such was by no means the case. I had performed many experiments in confirmation of Pasteur's germ theory, not indeed in order to satisfy myself of its truth, but in the hope of convincing others. I had observed that uncontaminated milk, which would remain

unaltered for an indefinite time if protected from dust, was made to teem with microbes of different kinds by a very brief exposure to the atmosphere, and that the same effect was produced by the addition of a drop of ordinary water. But when I came to experiment with blood drawn with antiseptic precautions into sterilized vessels, I saw, to my surprise, that it might remain free from microbes, in spite of similar access of air or treatment with water. I even found that if very putrid blood was largely diluted with sterilized water, so as to diffuse its microbes widely and wash them of their acrid products, a drop of such dilution added to pure blood might leave it unchanged for days at the the temperature of the body, although a trace of the septic liquid undiluted caused intense putrefaction within twenty-four hours. Hence I was led to conclude that it was the grosser forms of septic mischief, rather than microbes in the attenuated condition in which they existed in the atmosphere, that we had to dread in surgical practice. And at the London Medical Congress, in 1881, I hinted, when describing the experiments I have alluded to, that it might turn out possible to disregard altogether the atmospheric dust. But greatly as I should have rejoiced at such a simplification of our procedure, if justifiable, I did not then venture to test it in practice. I knew that with the safeguards which we then employed I could ensure the safety of my patients, and I did not dare to imperil it by relaxing them. There is one golden rule for all experiments upon our fellowmen. Let the thing tried be that which, according to our best judgment, is the most likely to promote the welfare of the patient. In other words, do as you would be done by.

Nine years later, however, at the Berlin Congress in 1890, I was able to bring forward what was, I believe, absolute demonstration of the harmlessness of the atmospheric dust in surgical operations. This conclusion has been justified by subsequent experience; the irritation of the wound by antiseptic irrigation and washing may therefore now be avoided, and nature left quite undisturbed to carry out her best methods of repair, while the surgeon may conduct his operations as simply as in former days, provided always that, deeply impressed with the tremendous importance of his object, and inspiring the same conviction in all his assistants, he vigilantly maintains from first to last, with care that, once learnt, becomes instinctive, but for the want of which nothing else can compensate, the use of the simple means which will suffice to exclude from the wound the coarser forms of septic impurity.

Even our earlier and ruder methods of carrying out the antiseptic principle soon produced a wonderful change in my surgical wards in the Glasgow Royal Infirmary, which, from being some of the most unhealthy in the kingdom, became, as I believe I may say without exaggeration, the healthiest in the world; while other wards, separated from mine only by a passage a few feet broad, where former modes of treatment were for a while continued, retained their former insalubrity. This result, I need hardly remark, was not in any degree due to special skill on my part, but simply to the strenuous endeavor to carry out strictly what seemed to me a principle of supreme importance.

Equally striking changes were afterwards witnessed in other institutions. Of these, I may give one example. In the great Allgemeines Krankenhaus, of Munich, hospital gangrene had become more and more rife from year to year, till at length the frightful condition was reached that 80 per cent. of all wounds became affected by it. It is only just to the memory of Professor von Nussbaum, then the head of that establishment, to say that he had done his utmost

to check this frightful scourge; and that the evil was not caused by anything peculiar in his management was shown by the fact that in a private hospital under his care there was no unusual unhealthiness. The larger institution seemed to have become hopelessly infected, and the city authorities were contemplating its demolition and reconstruction. Under these circumstances, Professor von Nussbaum dispatched his chief assistant, Dr. Lindpaintner, to Edinburgh, where I at that time occupied the chair of clinical surgery, to learn the details of the antiseptic system as we then practiced it. He remained until he had entirely mastered them, and after his return all the cases were on a certain day dressed on our plan. From that day forward not a single case of hospital gangrene occurred in the Krankenhaus. The fearful disease pyæma likewise disappeared, and erysipelas soon followed its example.

But it was by no means only in removing the unhealthiness of hospitals that the antiseptic system showed its benefits. Inflammation being suppressed, with attendant pain, fever and wasting discharge, the sufferings of the patient were, of course, immensely lessened; rapid primary union being now the rule, convalescence was correspondingly curtailed; while, as regards safety and the essential nature of the mode of repair, it became a matter of indifference whether the wound had clean-cut surfaces which could be closely approximated, or whether the injury inflicted had been such as to cause destruction of tissue. And operations which had been regarded from time immemorial as unjustifiable were adopted with complete safety.

It pleases me to think that there is an ever-increasing number of practitioners throughout the world to whom this will not appear the language of exaggeration. There are cases in which, from the situation of the part concerned or other unusual circumstances, it is impossible to carry out the antiseptic system completely. These, however, are quite exceptional; and even in them much has been done to mitigate the evil which can not be altogether avoided.

I ask your indulgence if I have seemed to dwell too long upon matters in which I have been personally concerned. I now gladly return to the labors of others.

The striking results of the application of the germ theory to surgery acted as a powerful stimulus to the investigation of the nature of the micro-organisms concerned; and it soon appeared that putrefaction was by no means the only evil of microbic origin to which wounds were liable. I had myself very early noticed that hospital gangrene was not necessarily attended by any unpleasant odor; and I afterwards made a similar observation regarding the matter formed in a remarkable epidemic of erysipelas in Edinburgh obviously of infective character. I had also seen a careless dressing followed by the occurrence of suppuration without putrefaction. And as these non-putrefactive disorders had the same self-propagating property as ferments, and were suppressed by the same antiseptic agencies which were used for combating the putrefactive microbes, I did not doubt that they were of an analogous origin; and I ventured to express the view that, just as the various fermentations had each its special microbe, so it might be with the various complications of wounds. This surmise was afterwards amply verified. Professor Ogston, of Aberdeen, was an early worker in this field, and showed that in acute abscesses, that is to say, those which run a rapid course, the matter, although often quite free from unpleasant odor, invariably contains micro-organisms belonging to the group which, from the spherical form of their elements, are termed micrococci; and these he classed as streptococci or staphylococci, according as they were arranged in chains or disposed in irregu-

lar clusters like bunches of grapes. The German pathologist, Fehleisen, followed with a beautiful research, by which he clearly proved that erysipelas is caused by a streptococcus. A host of earnest workers in different countries have cultivated the new science of bacteriology, and, while opening up a wide fresh domain of biology, have demonstrated in so many cases the causal relation between special micro-organisms and special diseases, not only in wounds, but in the system generally, as to afford ample confirmation of the induction which had been made by Pasteur that all infective disorders are of microbic origin.

Not that we can look forward with anything like confidence to being able to see the *materies morbi* of every disease of this nature. One of the latest of such discoveries has been that by Pfeiffer, of Berlin, of the bacillus of influenza, perhaps the most minute of all micro-organisms ever yet detected. The bacillus of anthrax, the cause of a plague common among cattle in some parts of Europe, and often communicated to sorters of foreign wool in this country, is a giant as compared with this tiny being; and supposing the microbe of any infectious fever to be as much smaller than the influenza bacillus as this is less than that of anthrax, a by no means unlikely hypothesis, it is probable that it would never be visible to man. The improvements of the microscope, based on the principle established by my father in the earlier part of the century, have apparently nearly reached the limits of what is possible. But that such parasites are really the causes of all this great class of diseases can no longer be doubted.

The first rational step towards the prevention or cure of disease is to know its cause; and it is impossible to over-estimate the practical value of researches, such as those to which I am now referring. Among their many achievements is what may be fairly regarded as the most important discovery ever made in pathology, because it revealed the true nature of the disease which causes more sickness and death in the human race than any other. It was made by Robert Koch, who greatly distinguished himself, when a practitioner in an obscure town in Germany, by the remarkable combination of experimental acuteness and skill, chemical and optical knowledge and successful micro-photography which he brought to bear upon the illustration of infective diseases of wounds in the lower animals; in recognition of which service the enlightened Prussian Government at once appointed him to an official position of great importance in Berlin. There he conducted various important researches; and at the London Congress, in 1881, he showed to us, for the first time, the bacillus of tubercle. Wonderful light was thrown, by this discovery, upon a great group of diseases which had before been rather guessed than known to be of an allied nature; a precision and efficacy never before possible was introduced into their surgical treatment, while the physician became guided by new and sure light as regards their diagnosis and prevention.

At that same London Congress Koch demonstrated to us his "plate culture" of bacteria, which was so important that I must devote a few words to its description. With a view to the successful study of the habits and effects of any particular microbe outside the living body it is essential that it should be present unmixed in the medium in which it is cultivated. It can be readily understood how difficult it must have been to isolate any particular micro-organism when it existed mixed, as was often the case, with a multitude of other forms. In fact, the various ingenious attempts made to effect this object had often proved entire failures. Koch, however, by an ingenious procedure converted what had been before impossible into a matter of the utmost facility. In the broth or other nutrient liquid which was to serve as food for the growing microbe

he dissolved, by aid of heat, just enough gelatine to ensure that, while it should become a solid mass when cold, it should remain fluid, though reduced in temperature so much as to be incapable of killing living germs. To the medium thus partially cooled was added some liquid containing, among others, the microbe to be investigated; and the mixture was thoroughly shaken so as to diffuse the bacteria and separate them from each other. Some of the liquid was then poured out in a thin layer upon a glass plate and allowed to cool so as to assume the solid form. The various microbes, fixed in the gelatine and so prevented from intermingling, proceeded to develop each its special progeny, which in course of time showed itself as an opaque speck in the transparent film. Any one of such specks could now be removed and transferred to another vessel in which the microbe composing it grew in perfect isolation.

Pasteur was present at this demonstration, and expressed his sense of the great progress effected by the new method. It was soon introduced into his own institute and other laboratories throughout the world; and it has immensely facilitated bacteriological study.

One fruit of it in Koch's own hands was the discovery of the microbe of cholera in India, whither he went to study the disease. This organism was termed by Koch from its curved form the "comma bacillus," and by the French the cholera vibrio. Great doubts were for a long time felt regarding this discovery. Several other kinds of bacteria were found of the same shape, some of them producing very similar appearances in culture media. But bacteriologists are now universally agreed that, although various other conditions are necessary to the production of an attack of cholera besides the mere presence of the vibrio, yet it is the essential *materies morbi;* and it is by the aid of the diagnosis which its presence in any case of true cholera enables the bacteriologist to make, that threatened invasions of this awful disease have of late years been so successfully repelled from our shores. If bacteriology had done nothing more for us than this it might well have earned our gratitude.

I have next to invite your attention to some earlier work of Pasteur. There is a disease known in France under the name of *choléra des poules,* which often produced great havoc among the poultry yards of Paris. It had been observed that the blood of birds that had died of this disease was peopled by a multitude of minute bacteria, not very dissimilar in form and size to the microbe of the lactic ferment to which I have before referred. And Pasteur found that, if this bacterium was cultivated outside the body for a protracted period under certain conditions, it underwent a remarkable diminution of its virulence; so that, if inoculated into a healthy fowl, it no longer caused the death of the bird, as it would have done in its original condition, but produced a milder form of the disease which was not fatal. And this altered character of the microbe, caused by certain conditions, was found to persist in successive generations cultivated in the ordinary way. Thus was discovered the great fact, of what Pasteur termed *atténuation du virus,* which at once gave the clue to understanding what had before been quite mysterious, the difference in virulence of the same disease in different epidemics.

But he made the further very important observation that a bird which had gone through the mild form of the complaint had acquired immunity against it in its most virulent condition. Pasteur afterwards succeeded in obtaining mitigated varieties of microbes for some other diseases; and he applied with great success the principle which he had discovered in fowl-cholera for protecting the larger domestic animals against the plague of anthrax. The preparations used for such preventive inoculations he termed "vaccins" in honor of our great

countryman, Edward Jenner. For Pasteur at once saw the analogy between the immunity to fowl-cholera produced by its attenuated virus and the protection afforded against smallpox by vaccination. And while pathologists still hesitated, he had no doubt of the correctness of Jenner's expression *variolæ vaccinæ*, or smallpox in the cow.

It is just a hundred years since Jenner made the crucial experiment of inoculating with smallpox a boy whom he had previously vaccinated, the result being, as he anticipated, that the boy was quite unaffected. It may be remarked that this was a perfectly legitimate experiment, involving no danger to the subject of it. Inoculation was at that time the established practice; and if vaccination should prove nugatory, the inoculation would be only what would have been otherwise called for; while it would be perfectly harmless if the hoped-for effect of vaccination had been produced.

We are a practical people, not much addicted to personal commemorations; although our nation did indeed celebrate, with fitting splendor, the jubilee of the reign of our beloved queen; and, at the invitation of Glasgow, the scientific world has lately marked, in a manner, though different, as imposing, the jubilee of the life-work of a sovereign in science (Lord Kelvin). But while we can not be astonished that the centenary of Jenner's immortal discovery should have failed to receive general recognition in this country, it is melancholy to think that this year should, in his native country, have been distinguished by a terrible illustration of the results which would sooner or later inevitably follow the general neglect of his prescriptions.

I have no desire to speak severely of the Gloucester Guardians. They are not sanitary authorities, and had not the technical knowledge necessary to enable them to judge between the teachings of true science and the declamations of misguided, though well-meaning, enthusiasts. They did what they believed to be right; and when roused to a sense of the greatness of their mistake, they did their very best to repair it, so that their city is said to be now the best vaccinated in Her Majesty's dominions. But though by their praiseworthy exertions they succeeded in promptly checking the raging epidemic, they can not recall the dead to life, or restore beauty to marred features, or sight to blinded eyes. Would that the entire country and our legislature might take duly to heart this object lesson!

How completely the medical profession were convinced of the efficacy of vaccination in the early part of this century was strikingly illustrated by an account given by Professor Crookshank, in his interesting history of this subject, of several eminent medical men in Edinburgh meeting to see the to them unprecedented fact of a vaccinated person having taken smallpox. It has, of course, since become well known that the milder form of the disease, as modified by passing through the cow, confers a less permanent protection than the original human disorder. This it was, of course, impossible for Jenner to foresee. It is, indeed, a question of degree, since a second attack of ordinary smallpox is occasionally known to occur, and vaccination, long after it has ceased to give perfect immunity, greatly modifies the character of the disorder and diminishes its danger. And happily, in revaccination after a certain number of years we have the means of making Jenner's work complete. I understand the majority of the commissioners, who have recently issued their report upon this subject, while recognizing the value of importance of revaccination, are so impressed with the difficulties that would attend making it compulsory by legislation that they do not recommend that course; although it is advocated by two of their number who are of peculiarly high authority on such a question. I was lately told by a Berlin professor that no serious difficulty is experienced in carrying out the compulsory

law that prevails in Germany. The masters of the schools are directed to ascertain in the case of every child attaining the age of twelve whether revaccination has been practiced. If not, and the parents refuse to have it done, they are fined one mark. If this does not prove effectual, the fine is doubled; and if even the double penalty should not prove efficacious, a second doubling of it would follow, but, as my informant remarked, it is very seldom that it is called for. The result is that smallpox is a matter of extreme rarity in that country; while it is absolutely unknown in the huge German army, in consequence of the rule that every soldier is revaccinated on entering the service. Whatever view our legislature may take on this question, one thing seems to me clear: that it will be the duty of government to encourage by every available means the use of calf lymph, so as to exclude the possibility of the communication of any human disease to the child, and to institute such efficient inspection of vaccination institutes as shall ensure careful antiseptic arrangements, and so prevent contamination by extraneous microbes. If this were done, "conscientious objections" would cease to have any rational basis. At the same time, the administration of the regulations on vaccination should be transferred (as advised by the commissioners) to competent sanitary authorities.

But to return to Pasteur. In 1880 he entered upon the study of that terrible but then most obscure disease, hydrophobia, or rabies, which from its infective character he was sure must be of microbic origin, although no microorganism could be detected in it. He early demonstrated the new pathological fact that the virus had its essential seat in the nervous system. This proved the key to his success in this subject. One result that flowed from it has been the cause of unspeakable consolation to many. The foolish practice is still too prevalent of killing the dog that has bitten any one, on the absurd notion that, if it were mad, its destruction would prevent the occurrence of hydrophobia in the person bitten. The idea of the bare possibility of the animal having been so affected causes an agony of suspense during the long weeks or months of possible incubation of the disease. Very serious nervous symptoms aping true hydrophobia have been known to result from the terror thus inspired. Pasteur showed that if a little of the brain or spinal cord of a dog that had been really mad was inoculated in an appropriate manner into a rabbit, it infallibly caused rabies in that animal in a few days. If, therefore, such an experiment was made with a negative result, the conclusion might be drawn with certainty that the dog had been healthy. It is perhaps right that I should say that the inoculation is painlessly done under an anesthetic, and that in the rabbit rabies does not assume the violent form that it does in the dog, but produces gradual loss of power, with little, if any, suffering.

This is the more satisfactory because rabbits in which the disease has been thus artificially induced are employed in carrying out what was Pasteur's greatest triumph, the preventive treatment of hydrophobia in the human subject. We have seen that Pasteur discovered that microbes might under some circumstances undergo mitigation of their virulence. He afterwards found that under different conditions they might have it exalted, or, as he expressed it, there might be a *renforcement du virus*. Such proved to be the case with rabies in the rabbit; so that the spinal cords of animals which had died of it contained the poison in a highly intensified condition. But he also found that if such a highly virulent cord was suspended under strict antiseptic precautions in a dry atmosphere at a certain temperature, it gradually from day to day lost its potency, till in course of time it became absolutely inert. If now

an emulsion of such a harmless cord was introduced under the skin of an animal, as in the subcutaneous administration of morphia, it might be followed without harm another day by a similar dose of a cord still rather poisonous; and so from day to day stronger and stronger ejections might be used, the system becoming gradually accustomed to the poison, till a degree of virulence had been reached far exceeding that of the bite of a mad dog. When this had been attained, the animal proved incapable of taking the disease in the ordinary way; and more than that, if such treatment was adopted after an animal had already received the poison, provided that too long a time had not elapsed, the outbreak of the disease was prevented. It was only after great searching of heart that Pasteur, after consultation with some trusted medical friends, ventured upon trying this practice upon man. It has since been extensively adopted in various parts of the world with increasing success as the details of the method were improved. It is not, of course, the case that every one bitten by a really rabid animal takes the disease; but the percentage of those who do so, which was formerly large, has been reduced almost to zero by this treatment, if not too long delayed.

While the intensity of rabies in the rabbit is undoubtedly due to a peculiarly virulent form of the microbe concerned, we can not suppose that the daily diminishing potency of the cord suspended in dry warm air is an instance of attenuation of virus, using the term "virus" as synonymous with the microbe concerned. In other words, we have no reason to believe that the special microorganism of hydrophobia continues to develop in the dead cord and produce successively a milder and milder progeny, since rabies can not be cultivated in the nervous system of a dead animal. We must rather conclude that there must be some chemical poison present which gradually loses its potency as time passes. And this leads me to refer to another most important branch of this large subject of bacteriology, that of the poisonous products of microbes.

It was shown several years ago by Roux and Yersin, working in the Institut Pasteur, that the crust or false membrane which forms upon the throats of patients affected with diphtheria contains bacteria which can be cultivated outside the body in a nutrient liquid, with the result that it acquires poisonous qualities of astonishing intensity, comparable to that of the secretion of the poison glands of the most venomous serpents. And they also ascertained that the liquid retained this property after the microbes had been removed from it by filtration, which proved that the poison must be a chemical substance in solution, as distinguished from the living element which had produced it. These poisonous products of bacteria, or toxins, as they have been termed, explain the deadly effects of some microbes, which it would otherwise be impossible to understand. Thus, in diphtheria itself, the special bacillus which was shown by Löffler to be its cause does not become propagated in the blood, like the microbe of chicken cholera, but remains confined to the surface on which it first appeared; but the toxin which it secretes is absorbed from that surface into the blood, and so poisons the system. Similar observations have been made with regard to the microbes of some other diseases, as, for example, the bacillus of tetanus or lockjaw. This remains localized in the wound, but forms a special toxin of extreme potency, which becomes absorbed and diffused through the body.

Wonderful as it seems, each poisonous microbe appears to form its own peculiar toxin. Koch's tuberculin was of this nature, a product of the growth of the tubercle bacillus in culture media. Here, again, great effects were produced by extremely minute quantities of the substance, but here a new peculiarity showed itself, *viz.*, that patients affected

with tubercular disease, in any of its varied forms, exhibited inflammation in the affected part and general fever after receiving under the skin an amount of the material which had no effect whatever upon healthy persons. I witnessed, in Berlin, some instances of these effects, which were simply astounding. Patients affected with a peculiar form of obstinate ulcer of the face showed, after a single injection of the tuberculin, violent inflammatory redness and swelling of the sore and surrounding skin; and, what was equally surprising, when this disturbance subsided the disease was found to have undergone great improvement. By repetitions of such procedures, ulcers which had previously been steadily advancing, in spite of ordinary treatment, became greatly reduced in size, and in some instances apparently cured. Such results led Koch to believe that he had obtained an effectual means of dealing with tubercular disease in all its forms. Unhappily, the apparent cure proved to be only of transient duration, and the high hopes which had been inspired by Koch's great reputation were dashed. It is but fair to say that he was strongly urged to publish before he was himself disposed to do so, and we can not but regret that he yielded to the pressure put upon him.

But though Koch's sanguine anticipations were not realized, it would be a great mistake to suppose that his labors with tuberculin have been fruitless. Cattle are liable to tubercle, and, when affected with it, may become a very serious source of infection for human beings, more especially when the disease affects the udders of cows, and so contaminates the milk. By virtue of the close affinity that prevails between the lower animals and ourselves, in disease as well as in health, tuberculin produces fever in tubercular cows in doses which do not affect healthy beasts. Thus, by the subcutaneous use of a little of the fluid, tubercle latent in internal organs of an apparently healthy cow can be with certainty revealed, and the slaughter of the animal after this discovery protects man from infection.

It has been ascertained that glanders presents a precise analogy with tubercle as regards the effects of its toxic products. If the microbe which has been found to be the cause of this disease is cultivated in appropriate media it produces a poison which has received the name of mallein, and the subcutaneous injection of a suitable dose of this fluid into a glandered horse causes striking febrile symptoms which do not occur in a healthy animal. Glanders, like tubercle, may exist in insidious latent forms which there was formerly no means of detecting, but which are at once disclosed by this means. If a glandered horse has been accidentally introduced into a large stable this method of diagnosis surely tells if it has infected others. All receive a little mallein. Those which become affected with fever are slaughtered, and thus not only is the disease prevented from spreading to other horses, but the grooms are protected from a mortal disorder.

This valuable resource sprang from Koch's work on tuberculin, which has also indirectly done good in other ways. His distinguished pupil, Behring, has expressly attributed to those researches the inspiration of the work which led him and his famous collaborator, the Japanese Kitasato, to their surprising discovery of antitoxic serum. They found that if an animal of a species liable to diphtheria or tetanus received a quantity of the respective toxin, so small as to be harmless, and afterwards, at suitable intervals, successively stronger and stronger doses, the creature, in course of time, acquired such a tolerance for the poison as to be able to receive with impunity a quantity very much greater than would at the outset have proved fatal. So far we have nothing more than seems to correspond with the effects of the increasingly potent

cords in Pasteur's treatment of rabies. But what was entirely new in their results was that, if blood was drawn from an animal which had acquired this high degree of artificial immunity, and some of the clear fluid or serum which exuded from it after it had clotted was introduced under the skin of another animal, this second animal acquired a strong, though more transient, immunity against the particular toxin concerned. The serum in some way counteracted the toxin or was antitoxic. But, more than that, if some of the antitoxic serum was applied to an animal after it had already received a poisonous dose of the toxin it preserved the life of the creature, provided that too long a time had not elapsed after the poison was introduced. In other words, the antitoxin proved to be not only preventive but curative.

Similar results were afterwards obtained by Ehrlich, of Berlin, with some poisons not of bacterial origin, but derived from the vegetable kingdom; and quite recently the independent labors of Calmette, of Lille, and Fraser, of Edinburgh, have shown that antidotes of wonderful efficacy against the venom of serpents may be procured on the same principle. Calmette has obtained antitoxin so powerful that a quantity of it only a 200,000th part of the weight of an animal will protect it perfectly against a dose of the secretion of the poison glands of the most venomous serpents known to exist, which, without such protection, would have proved fatal in four hours. For curative purposes larger quantities of the remedy are required, but cases have been already published by Calmette in which death appears to have been averted in the human subject by this treatment.

Behring's darling object was to discover means of curing tetanus and diphtheria in man. In tetanus the conditions are not favorable; because the specific bacilli lurk in the depths of the wound, and only declare their presence by symptoms caused by their toxin having been already in a greater or less amount diffused through the system; and in every case of this disease there must be a fear that the antidote may be applied too late to be useful. But in diphtheria the bacilli very early manifest their presence by the false membrane which they cause upon the throat, so that the antitoxin has a fair chance; and here we are justified in saying that Behring's object has been attained.

The problem, however, was by no means so simple as in the case of some mere chemical poison. However effectual the antitoxin might be against the toxin, if it left the bacilli intact, not only would repeated injections be required to maintain the transient immunity to the poison perpetually secreted by the microbes, but the bacilli might, by their growth and extension, cause obstruction of the respiratory passages.

Roux, however, whose name must always be mentioned with honor in relation to this subject, effectually disposed of this difficulty. He showed by experiments on animals that a diphtheritic false membrane, rapidly extending and accompanied by surrounding inflammation, was brought to a stand by the use of the antitoxin, and soon dropped off, leaving a healthy surface. Whatever be the explanation, the fact was thus established that the antitoxic serum, while it renders the toxin harmless, causes the microbe to languish and disappear.

No theoretical objection could now be urged against the treatment; and it has during the last two years been extensively tested in practice in various parts of the world, and it has gradually made its way more and more into the confidence of the profession. One important piece of evidence in its favor in this country is derived from the report of the six large hospitals under the management of the London Asylums Board. The medical officers of these hospitals at first naturally regarded the practice with scepticism, but as it appeared to be at

least harmless they gave it a trial; and during the year 1895 it was very generally employed upon the 2,182 cases admitted, and they have all become convinced of its great value. In the nature of things, if the theory of the treatment is correct, the best results must be obtained when the patients are admitted at an early stage of the attack, before there has been time for much poisoning of the system, and accordingly we learn from the report that, comparing 1895 with 1894, during which latter year the ordinary treatment had been used, the percentage of mortality, in all the six hospitals combined, among the patients admitted on the first day of the disease, which in 1894 was 22.5, was only 4.6 in 1895; while for those admitted on the second day the numbers are 27 for 1894 and 14.8 for 1895. Thus for cases admitted on the first day the mortality was only one fifth of what it was in the previous year, and for those entering on the second it was halved. Unfortunately, in the low parts of London, which furnish most of these patients, the parents too often delay sending in the children till much later, so that on the average no less than 67.5 per cent. were admitted on the fourth day of the disease or later. Hence the aggregate statistics of all cases are not nearly so striking. Nevertheless, taking it altogether, the mortality in 1895 was less than had ever before been experienced in those hospitals. I should add that there was no reason to think that the disease was of a milder type than usual in 1895; and no change whatever was made in the treatment except as regards the antitoxic injections.

There is one piece of evidence recorded in the report which, though it is not concerned with high numbers, is well worthy of notice. It relates to a special institution to which convalescents from scarlet fever are sent from all the six hospitals. Such patients occasionally contract diphtheria, and when they do so the added disease has generally proved extremely fatal. In the five years preceding the introduction of the treatment with antitoxin the mortality from this cause had never been less than 50 per cent., and averaged on the whole 61.9 per cent. During 1895, under antitoxin, the deaths among the 119 patients of this class were only 7.5 per cent., or one eighth of what had been previously experienced. This very striking result seems to be naturally explained by the fact that these patients being already in hospital when the diphtheria appeared, an unusually early opportunity was afforded for dealing with it.

There are certain cases of so malignant a character from the first that no treatment will probably ever be able to cope with them. But taking all cases together, it seems probable that Behring's hope that the mortality may be reduced to five per cent. will be fully realized when the public become alive to the paramount importance of having the treatment commenced at the outset of the disease.

There are many able workers in the field of bacteriology whose names time does not permit me to mention, and to whose important labors I can not refer; and even those researches of which I have spoken have been, of course, most inadequately dealt with. I feel this especially with regard to Pasteur, whose work shines out more brightly the more his writings are perused.

I have lastly to bring before you a subject which, although not bacteriological, has intimate relations with bacteria. If a drop of blood is drawn from the finger by a prick with a needle and examined microscopically between two plates of glass, there are seen in it minute solid elements of two kinds, the one pale orange bi-concave discs, which, seen in mass, give the red color to the vital fluid, the other more or less granular spherical masses of the soft material called protoplasm, destitute of color, and therefore called the colorless or white corpuscles. It has been long known that if the microscope was placed at such a distance from

a fire as to have the temperature of the human body, the white corpuscles might be seen to put out and retract little processes or pseudopodia, and by their means crawl over the surface of the glass, just like the extremely low forms of animal life termed, from this faculty of changing their form, amœbæ. It was a somewhat weird spectacle, that of seeing what had just before been constituents of our own blood moving about like independent creatures. Yet there was nothing in this inconsistent with what we knew of the fixed components of the animal frame. For example, the surface of a frog's tongue is covered with a layer of cells, each of which is provided with two or more lashing filaments or cilia, and those of all the cells acting in concert cause a constant flow of liquid in a definite direction over the organ. If we gently scrape the surface of the animal's tongue we can detach some of these ciliated cells; and on examining them with the microscope in a drop of water we find that they will continue for an indefinite time their lashing movements, which are just as much living or vital in their character as the writhings of a worm. And, as I observed many years ago, these detached cells behave under the influence of a stimulus just like parts connected with the body, the movements of the cilia being excited to greater activity by gentle stimulation, and thrown into a state of temporary inactivity when the irritation was more severe. Thus each constituent element of our bodies may be regarded as in one sense an independent living being, though all work together in marvelous harmony for the good of the body politic. The independent movements of the white corpuscles outside the body were therefore not astonishing; but they long remained matters of mere curiosity. Much interest was called to them by the observation of the German pathologist Cohnheim that in some inflammatory conditions they passed through the pores in the walls of the finest blood vessels, and thus escaped into the interstices of the surrounding tissues. Cohnheim attributed their transit to the pressure of the blood. But why it was that, though larger than the red corpuscles, and containing a nucleus which the red ones have not, they alone passed through the pores of the vessels, or why it was that this emigration of the white corpuscles occurred abundantly in some inflammations and was absent in others, was quite unexplained.

These white corpuscles, however, have been invested with extraordinary new interest by the researches of the Russian naturalist and pathologist Metchnikoff. He observed that, after passing through the walls of the vessels, they not only crawl about like amœbæ, but, like them, receive nutritious materials into their soft bodies and digest them. It is thus that the effete materials of a tadpole's tail are got rid of; so that they play a most important part in the function of absorption.

But still more interesting observations followed. He found that a microscopic crustacean, a kind of water-flea, was liable to be infested by a fungus which had exceedingly sharp-pointed spores. These were apt to penetrate the coats of the creature's intestine, and project into its body cavity. No sooner did this occur with any spore than it became surrounded by a group of the cells which are contained in the cavity of the body and correspond to the white corpuscles of our blood. These proceeded to attempt to devour the spore, and if they succeeded in every such case the animal was saved from the invasion of the parasite. But if the spores were more than could be disposed of by the devouring cells (phagocytes, as Metchnikoff termed them) the water-flea succumbed.

Starting from this fundamental observation, he ascertained that the microbes of infective diseases are subject to this same process of devouring and

digestion, carried on both by the white corpuscles and by cells that line the blood-vessels. And by a long series of most beautiful researches he has, as it appears to me, firmly established the great truth that phagocytosis is the main defensive means possessed by the living body against the invasion of its microscopic foes. The power of the system to produce antitoxic substances to counteract the poisons of microbes is undoubtedly in its own place of great importance. But in the large class of cases in which animals are naturally refractory to particular infective diseases the blood is not found to yield any antitoxic element by which the natural immunity can be accounted for. Here phagocytosis seems to be the sole defensive agency. And even in cases in which the serum does possess antitoxic, or, as it would seem in some cases, germicidal properties, the bodies of the dead microbes must at last be got rid of by phagocytosis, and some recent observations would seem to indicate that the useful elements of the serum may be, in part at least, derived from the digestive juices of the phagocytes. If ever there was a romantic chapter in pathology, it has surely been that of the story of phagocytosis.

I was myself peculiarly interested by these observations of Metchnikoff's, because they seemed to me to afford clear explanation of the healing of wounds by first intention under circumstances before incomprehensible. This primary union was sometimes seen to take place in wounds treated with water-dressing, that is to say, a piece of wet lint covered with a layer of oiled silk to keep it moist. This, though cleanly when applied, was invariably putrid within twenty-four hours. The layer of blood between the cut surfaces was thus exposed at the outlet of the wound to a most potent septic focus. How was it prevented from putrefying, as it would have done under such influence if, instead of being between divided living tissues, it had been between plates of glass or other indifferent material? Pasteur's observations pushed the question a step further. It now was, How were the bacteria of putrefaction kept from propagating in the decomposable film? Metchnikoff's phagocytosis supplied the answer. The blood between the lips of the wound became rapidly peopled with phagocytes, which kept guard against the putrefactive microbes and seized them as they endeavored to enter.

If phagocytosis was ever able to cope with septic microbes in so concentrated and intense a form, it could hardly fail to deal effectually with them in the very mitigated condition in which they are present in the air. We are thus strongly confirmed in our conclusion that the atmospheric dust may safely be disregarded in our operations, and Metchnikoff's researches, while they have illumined the whole pathology of infective diseases, have beautifully completed the theory of antiseptic treatment in surgery.

I might have taken equally striking illustrations of my theme from other departments in which microbes play no part. In fact any attempt to speak of all that the art of healing has borrowed from science and contributed to it during the past half century would involve a very extensive dissertation on pathology and therapeutics. I have culled specimens from a wide field; and I only hope that in bringing them before you I have not overstepped the bounds of what is fitting before a mixed company. For many of you my remarks can have had little if any novelty; for others they may perhaps possess some interest as showing that medicine is no unworthy ally of the British Association; that, while her practice is ever more and more based on science, the ceaseless efforts of her votaries to improve what have been fittingly designated *Quæ prosunt omnibus artes* are ever adding largely to the sum of abstract knowledge.

PROGRESS AND THE SCIENCES

By Dr. WALTER W. LUCASSE
THE UNIVERSITY OF PENNSYLVANIA

THE Stone Age; the Bronze Age; the Iron Age; and this? The Age of Science; and it is little wonder that many have so characterized it. We hear of research being carried on in all the great industries, of vast sums being raised for research and of achievements made possible only by the aid of science. One sometimes wonders whether we are passing blindly through this age of science as did, we may think, the dwellers of the earlier eras. Or is the present period more purposeful? Has science itself an aim and if so are we, at present, sufficiently scientifically minded to relate the scientific aim to the age and cause a purposeful development?

No one can truly answer these questions in all their significance and doubtlessly each who tried would have a different answer. One has but to read such essays as "Daedalus," by Haldane, and "Icarus," by Russell, to see how differently science with respect to the future may be looked upon; or to witness such a drama as "R. U. R." to have material and mechanical progress appear in a somewhat different light from that in which we usually view it. It is well, perhaps, in view of all the appeals for financial aid, the endowed research institutes and the publicly supported government laboratories, that those who have tried to look at the matter broadly should attempt, from time to time, to draw the thing as they see it.

Surely there can be no question but what science has given us a multitude of mechanical devices, but if we consider the complexity these have added to life we may well wonder whether they have contributed one drop of true and lasting happiness to our brimming cup. Moreover, those whom we think of as scientists are, in general, not concerned with these applications when toiling in their remote laboratories. When the expansion of steam under pressure was first studied, the worker little dreamed of the transcontinental railways which would soon spread like a net-work over all countries. And when Faraday first passed a wire over a magnet the unending possibilities of the electrical dynamo were not his aim. The names which appear above the articles in our scientific journals to-day are not, for the most part, those of men who are in any way relating science to the everyday life of man. The authors are more interested in the broad generalizations of pure science and are inclined to scoff at applied science. Yet with delightful inconsistency they will rise with one accord if asked why they are pursuing science, and say that without the advancement of pure science in this generation man's material progress in the next will be halted. How good they are to work without personal reward that their children's children may have bread enough and to spare—and unending mechanical devices to add to the complexity of life! Few would admit that science is a high-class sport enjoyed by certain high-class minds. They must rather hallow their labors before the imaginary shrine of nations yet unborn rising to sing their praise. It would be cruel to puncture their holiness with such words as ambition, self-esteem, self-aggrandizement or some of the psychological terms of

motivation such as compensation, will-to-power, Jehovah complex.

Artists and writers have beheld the works of their hands and said, "It is good." It is said that when Händel completed the Hallelujah Chorus he was so overwhelmed with the beauty of his creation that he imagined he saw the heavens open before him and angels ascending and descending. Thackeray often interrupted his work on "Vanity Fair" to march up and down the room exclaiming, "That's genius." Ah, but the scientist is of different clay! He will rarely admit any such joys in his labors.

Some one has spoken of the scientists as the "saints of the twentieth century." The majority, in this money-mad day, would prefer, looking at his baggy knees and empty purse, to call the scientist a fool. To himself he may often admit the latter, but to the world he coyly implies the former. Doubtlessly the truth is that he is just the proper mixture of saint and fool to make him completely human and just what he is—not to be praised for his high-sounding altruism for the future nor yet to be pitied for the pleasant hardships he causes himself and those dependent upon him. Perhaps the scientists, the artists, the writers—all of us—are mere pawns upon this checkerboard of nights and days, one sent hither by his particular glandular balance, another thither by his ancestry or his reactions to environment.

But whether the scientist is sincere and purposeful in his work or not, there can be no doubt of his results. All our "modern conveniences" are the result of scientific inquiry and application—some few work out in the laboratories of the companies selling the products at a few hundred per centum profit, the majority developed on the heritage of the past, built up by those interested in pure science. Nowhere is it truer than in science that one generation shall labor and another shall enter into the fruits of its labors. In the middle eighties of the last century, a chemist prepared dichloroethylsulfide. In 1918 every one called it by a simpler name—"mustard gas." What an unfortunate example! And yet how few are the examples of the achievements of science which are wholly without unfortunate aspects if we look at the full possibilities. The industry which grasps the nitrogen from the air and with its fertilizers multiplies the yield of our vast acreage may tomorrow send forth the munitions which will strew those same fields with human wreckage. The radio may fill the nights with music or it may turn back the pages of science and teach the multitudes that the earth is flat. The telegraph may one day spread joy with the news that the income tax has been reduced half of one per centum, and next day sorrow at the news that families will be split asunder in each petty nation in order that their individual coinage may be made safe for their monied classes. The same reproducing device which may lift our souls to the heights of a grand symphony may also cause us to respond once more to the pulse of primitive strains. The food which science has given us is better and more varied than that of kings of yesteryear, but this very blessing has given us many a sleepless night, and 'twould be a happy bargain if we could trade our teeth for theirs. The automobile may be a pleasure and a business necessity, but little permanent value can it offer to the group or the individual if its acquirement by easy payment plans obligates the future to decreasing currency values and forced increased production. The mortgaging of homes to satisfy the cravings of a world on pleasure bent may reduce us to a new form of wandering tribes, the very wealthy migrating from one palatial residence to another, the

poor journeying in worn-out vehicles from one place of short employment to another. The morning paper gives us news from all corners of the earth of war, pestilence and famine; the murders, suicides and robberies; the sorrows and intrigues of the world are laid before us at breakfast and the evening paper adds the daring daylight hold-ups. And so on, examples showing the pleasant results and likewise the equally unpleasant consequences and dangers of applied science could be added without end.

But if this is all, the shortening of time and space, a few new toys of questionable merit—a little louder but as empty quite—is not the clown, the actor, the artist, he who carries us away with his songs, he who gives us a brief flight from reality by the joys and sorrows of his imaginary characters, are not these to be more blessed than the scientist? For each in his own way permits us for a moment to forget the cares that infest the day.

Before we consider these questions further, we may look upon science as doing other things. Not only is it building from the gifts of nature, but it is constantly carrying on a battle with nature. We tower into the sky our great cathedrals of commerce, and before the last stone is in place nature urges the brick and steel and mortar to crumble. We span the broad rivers in order that they shall no longer be barriers to our speed, but e'er the last cable is spun wind and weather have started the work which, were it not for man's constant vigilance, would one day carry the mighty structure down stream. We modify plants and animals for our use, but always battling against the force which would cause them to revert. Even greater than these is the struggle of science to make man master of the entire globe until the sun goes down for the last time. At will, the deserts are converted into fertile fields; rich tropical areas are placed at man's disposal by scientific sanitation; the frozen regions to the north and south recede before his material progress. The conquest over climate is of such far-reaching possibility that as the earth gradually changes temperature, science will make man the master over this change, not completely, perhaps, but sufficiently to stretch the span of human existence upon this globe a little more nearly to the time when another planet sweeps too close and we melt once more into star dust.

But if the dark pictures of the dangers of science are true, if life like a pendulum swings from pain to ennui and back again to pain, if each of us would end all were it not that this demands a positive act, not against the will to live but against the animal that is our being, if all these things are true, should we then be grateful to the scientist who not only lengthens human life but the span of existence of the race?

For the answer, as we see it, to this recurrent question we must wait until we have looked somewhat more closely to see what we mean by science. So far, we have tacitly assumed by this term the exact sciences, those which are in the main responsible for our material progress, such as physics and chemistry. What of the contributions of the sciences which are less subject to mathematical treatment, such as psychology and sociology? We may question whether this distinction is a real one or merely one of convenience. Alchemy, the forerunner of chemistry, was far from mathematical. At a somewhat later period, Lavoisier introduced the extensive use of the balance into the chemistry of his day and it was then started on its way to becoming the highly mathematical science which it now is, with numerical tables and equations filling the pages of our journals of physical chemistry. As as-

tronomy developed, whole new branches of mathematics were built up to fill its needs. Perhaps as a science becomes older it becomes more subject to exact treatment, and the above distinction may be one of age only. Already in psychology we hear much of "the mysterious I. Q." and of correlation coefficients. Are these the first steps in the progression from numbers to ratios and then numerical relationships which mark the way to long and involved equations? If such is the case, the social and natural sciences will alike be exact.

Let us take a couple of examples from each class and see if we can distinguish a fundamental difference. Some one has said that when a feather falls to the ground, the earth is displaced from its axis. Not only this, but we can calculate the amount of displacement. True, the infinitesimal value which we obtain will not be the actual amount which the earth has moved from its axis in that instant, for at the same time there were other feathers falling, many leaves dropping from trees, trains crossing mountains and ships crossing seas. What, then, has our calculator done? He has limited the variables and given us the figure which the earth would move were all the rest of the mass of the universe stationary. Such is the legitimate procedure of the exact sciences. From the social sciences we learn that a certain percentage of any group may be classed as drunkards. Just as we limited our example in the previous case to a single feather let us here consider a single individual. But whereas with the group our percentage had a significance, now the figure is without meaning, no matter how much we limit our consideration of the forces bearing upon the situation—age, ancestry, environment, sex, color or creed, and we can not say that the individual is such a per centum drunkard nor can we say he is intoxicated such a part of the time. Even if the individual is the child of drunken parents, we can not say that he will become a drunkard, only that he may perhaps have a tendency toward the use of intoxicants. Doubtlessly no one would attempt to draw conclusions regarding the individual from group statistics in this particular case, but it would not be difficult to find slightly more complicated instances where the fallacy of this type of reasoning is less obvious and where one might be tempted to draw conclusions which would be equally untenable in passing from a statistical study to the consideration of a few or of an individual. Factors which tend to produce effects when the group is considered as a whole may be entirely lacking in certain members and thus we can not segregate the forces in discussing the individual as we did in the physical example. Too many unknown influences enter the social example to permit us to limit the system or its variables with any resultant meaning.

Or let us look at the matter from another viewpoint. We learn from chemistry that if sodium and chlorine are brought together common salt will result. Indeed, if a single atom of sodium is caused to react with a single atom of chlorine we may unhesitatingly predict that a molecule of sodium chloride, with all its characteristic properties, will be formed. May we likewise predict that the child of college graduates, each of high intelligence, will be the intellectual equal of its parents? In general, we find that superior parents will give birth to children of superior ability, but alas the same sociological data and psychological tests which give us this generalization have often shown that there may be a mite of truth in the highly exaggerated saying that the campuses of certain of our universities are flooded with the idiot children of the faculty. In our

chemical example, limiting the units from gross masses to atoms brought no lessening of the accuracy of our prediction, but in our example from the less exact sciences we reached only "probably." And in this very difference may lie some of the hope for science as an agent of human welfare.

To be sure, no one would be so bold as to suggest that the social sciences will not become more exact and mathematical as time goes on. Indeed, this is doubtlessly what will occur. Nor should it be understood that statistical methods are not used in the exact sciences, for certain of the outstanding achievements of modern physics and chemistry are due to the application of such devices. But it seems more than likely that there will ever be a gradation in the sciences, from mathematics itself through the physical sciences, the biological sciences, the social sciences, even, if we may include it, to philosophy. And this gradation will depend upon the number of factors we are able to limit; the fewer we are able to limit the more will we be confined to group descriptions and indications rather than led to predictions and certainties.

Without this difference perhaps the world would force the results of the social sciences into the extreme utilitarian aspects of the exact sciences, and with studied social environment, ancestry and intelligence measurements, a new system of castes might grow up in which the "thousands who humble and nameless the straight, hard pathway trod" would be even more humble and nameless. Under such a system we might well wonder what would have become of Faraday, who was born the third child of a blacksmith and rose to first rank among the scientists of his day, or of the many artists and musicians who have risen above adverse circumstances of poverty and environment. The merits of the social sciences, too, may then be raised to question if we forget the limitations imposed by their general methods.

How then may we be sure for ourselves and posterity of the benefits of science without its dangers? Surely no one who has experienced the comforts of our materialistic progress would urge us to turn back in the hope of finding a Nirvana of contentment rather than to face the possible dangers of science. Nor yet would we wish blindly to pursue science if it is, as many have suggested, a powerful monster which may one day crush its creator. But conscious change for permanent betterment has never been in the direction of turning backward toward a darker age. We must ever face reality and take from each passing step the contributions which seem most fruitful for future welfare. Perhaps, after all, the pleasures of the present and the safety of the future lie in science, not in the exact sciences alone, nor yet the social sciences alone, but in the whole mass and development of organized knowledge and directed curiosity which we know as science and scientific research.

In viewing the possible dangers of the material development of exact science, many in that field have suggested that it is not their responsibility to what use society at large puts their discoveries. They have held that society and society alone is responsible for the use or misuse of the knowledge which is placed in its hands. But when we consider the fact that the army tests showed us to be intellectually a nation of sixth graders—and perhaps the rest of the world is not far different—we may suspect that the responsibility has been passed on to a not too well-trained guardian. It is almost akin to removing the responsibility from a parent for the consequences of permitting his child to play with firearms. If the exact scientist is not will-

ing to take the responsibility for the results of his labors let him realize the fallacy of the belief that all men were created equal and pass the stewardship into the hands of those who are close to society and yet at the same time are members of the aristocracy of brains.

In this, perhaps, lies one of the broadest fields of the social scientists, to guide society into the right use of science, to protect mankind from its misuse, to turn the ever-increasing knowledge to the greatest happiness of the masses. Theirs is the task of keeping us from the devastations of war, of securing for us the right uses of the material progress afforded by science, of showing us how best to use the ever-increasing leisure which science has given us by decreasing the working hours, of guarding us from the hysteria of our fast methods of travel and communication. It is the opportunity of the philosophers and the social scientists to give us new faiths and ideals compatible with our new knowledge to replace those which biology and certain other branches of science have shattered. Theirs is the duty to show us that the doubts which they themselves have raised, that teachings such as those of Schopenhauer, though true perhaps in a measure, are but challenges to master the science of living.

In addition to the guidance which the social scientists can give us, we must have an ever-increasing spirit of science bred in the masses in order to protect us from the too material aspects of the exact sciences. Through formal education, popular lectures and books and articles made intelligible to the general public, the broad teachings of science will become part of the underlying thought of the race. Not that all will grasp the subject-matter of even a single branch of science, but that slowly the method of thinking and attitude of science will become a part of the everyday life of the people. All the qualities which are essential for the happiness of individuals living in large groups, for the progress and well-being of the race as a whole, result from the cardinal principles of science. They are the methods and attitudes of science, irrespective of the particular subject-matter. Patience, discipline, logical thought, original work, dignity of both mental and manual labor—these are to be found in science. Regard for truth and for the opinions of others, critical faculty, moral responsibility, self-sacrifice, higher views of life—all these are found in science. With a general assimilation of the methods of approach and teachings of science these qualities will slowly become the virtues of the race.

In viewing, then, this scientific age we should realize that we are dealing with a great two-edged sword which we can not treat compromisingly. We must face it wholly, with all its possibilities for good and evil. We must realize that we are working with a science of things and a science of men; that both need development, the one for man's material progress, the other to protect him from too much materialization. We should keep before us the certainty of prediction of the exact sciences and the equally helpful limitations of the social sciences. Lavoisier has been spoken of as the last chemist. Since his time chemists have been organic chemists, inorganic, physical, and specialists in many other branches. So with all science, great specialization is necessary, but at the same time for the greatest good to mankind cooperation both in its pursuit and its development is essential. Our encouragement, financial, moral and active, should be not to one science nor yet to one group of sciences, but to the whole mass of growing knowledge. We should take advantage of and encourage the labors of that group of workers who

style themselves scientists and delve into the mysteries of nature without themselves being able to give a true—surely not a unanimous—reason for their zeal.

Many of the blessings of science can be obtained, in addition to the flexible grants of public monies, by the endowment of institutions of liberal charter. But let them be so flexible that as new needs arise—indeed, new sciences—we shall no longer be compelled to resort to the practice "where there's a will there's a lawyer." How much better would it be if the money left to institutions for public good should become the free and unencumbered property of the institutions after twenty years. Then we would no longer have to read into a gift for the care of young mothers a child guidance clinic, nor into a gift for beautifying a college campus a group of much needed buildings.

> Yesterday this day's madness did prepare;
> To-morrow's silence, triumph or despair.

Which of these will be to-morrow's fate will depend, perhaps, upon whether we are able to look upon science broadly and develop it purposefully.

JAN JACOBZ SWAMMERDAM

By Dr. HARRY B. WEISS

NEW JERSEY DEPARTMENT OF AGRICULTURE

DURING the Thirty Years' War the interior of The Netherlands was free from the devastating effects of Protestantism and Catholicism *en combat*, and the Dutch, under an economic policy directed by able administrators, grabbed the commerce of the world and increased their maritime power. With great success the Dutch East India Company exploited Asia and made war on Spain, and the West India Company operated in America and Africa. Every one was interested in making money. The Indian merchants and their friends wallowed in wealth and spent their money lavishly on silks, velvets, pearls, pictures, expensive furnishings, porcelain ware and objects of art from all parts of Europe and Asia. The people were prosperous, the arts flourished and Amsterdam was the world center of wealth and commerce.

Always fond of tulips and ornamental gardens, and with an abundance of money, the people spent freely on their gardens, and it was not strange that the passion for planting became general. This in turn stimulated the growing of tulips, and many persons saw therein an opportunity for becoming rich quickly. Various shades, colors and shapes were sought for and prices rose. Hundreds went into the culture expecting to become opulent over night by propagating the expensive varieties. Speculation and gambling replaced caution and thrift. Certain varieties brought astonishing prices; 2,500 gulden for a single bulb, and once 4,000 gulden. Brokers sold bulbs they did not have and wild speculation set in. Huge sums were made and lost. From 1634 until 1637, the tulip dementia raged and then the bubble burst.

During this craze was born one of the great biologists of the seventeenth century, John Swammerdam, in Amsterdam, on February 12, 1637, son of John James Swammerdam and Barentje Corver. From his birth he was surrounded by fossils, dried insects, minerals, stuffed animals, Chinese porcelain, curios from the Indies, pills, mithridates and elixirs, his father having been both a druggist and a collector whose assemblage of rare and unusual objects was locally celebrated. In such an atmosphere the boy developed a liking for natural history and he too collected—small animals, insects, from the surrounding streams and fields. And in addition, he was curator of his father's cabinet.

At first his education took the shape of a training for the church, and he studied Greek and Latin. However, feeling that he was not fitted for such a pursuit, he began, with his parents' consent, the study of medicine, and in 1661 traveled to Leyden, where he stayed for two years studying surgery with Van Horne and medicine with Franciscus Sylvius de la Boë, who was the first to evolve an entire system of medicine founded on chemistry. Here he became friendly with Nicholas Stensen, who in 1663 described the true structure of the heart, and with Regner de Graaf, of ovarian follicle fame. In 1663 he went to Saumur where he studied insects and made known in a letter to Stensen in 1664 the discovery of the valves of the lymphatic vessels. As Ruysch discovered the same thing a little later, Swammerdam thought that Ruysch had seen

his drawings. Then to Paris where he was entertained generously by Melchisedec Thevenot, formerly the French king's minister at Genoa, who had a country home just outside of Paris. Here he met various notables, but being rather sparing of words he had very little to say at these gatherings.

Upon his return to Amsterdam he got permission to examine the bodies of hospital patients who had died and here he diligently studied anatomy, specializing on the structure of the spinal cord. Towards the end of 1666 he returned to Leyden for his degree, and in 1661 he was made a Doctor of Medicine and published his thesis on respiration in which he tried to show that "air entered the lungs because it became rarefied in the mouth and that the atmosphere became condensed within the chest when it expanded." This theory, first thought of by Descartes, was known as the Cartesian Circle. He also became quite expert in varicus methods of injection, and invented the art of wax injection which was perfected later by Ruysch, thereby greatly stimulating the study of minute anatomy.

Due to intense concentration on his work, Swammerdam's health began to fail about this time, and he was also stricken by malarial fever. Upon his recovery he discontinued his medical work for two years and again began the study of insects. In 1668 he had an opportunity to go to Florence. The Grand Duke of Tuscany, who visited Amsterdam in 1668 and who was taken by Thevenot to see Swammerdam and the museum, was so amazed by Swammerdam's skill in dissecting that he offered 12,000 florins for the collection, stipulating, however, that Swammerdam should accompany it back to Florence and enter his service. This Swammerdam refused to do, probably because court life did not appeal to him, but perhaps mainly because he was Protestant and could not accept the teachings of Roman Catholicism. His friend Stensen had become in 1666 the head of a hospital in Florence and physician to the duke, and a year later he accepted the Catholic faith and from then on took orders until 1675, when he was made a priest. He then discontinued his scientific studies and a year or so later he was made a bishop and returned to the northern Protestant countries as a missionary.

In 1669 Swammerdam published his "General History of Insects" which was dedicated to the Amsterdam senate. Some of his own money had been spent in the collection of specimens for this work, and its publication did not add to his income. Such an unprofitable course displeased his father, who urged him to forget insects and practice medicine. Although this was good advice from a financial viewpoint, Swammerdam was reluctant to follow it. At this time, suffering from another attack of malaria, he retired to the country to regain his health. Once in the fields, he was soon hard at work again on his beloved natural history, studying among other things the life history of the hive-bee and of the Ephemera.

In ill health, and depressed, his thoughts turned more and more to religion and while in this frame of mind he was greatly impressed by some of the ideas of Antoinette Bourignon, a Flemish religious zealot, who scattered her divine wisdom and emotional mysticism in the Netherlands and adjoining parts of Germany. As Swammerdam, during the remainder of his life, was guided more or less by her teachings, it is of interest to know their content.

Antoinette Bourignon, born at Lille in 1616, apparently had a hectic time during most of her life. As a child she was positively ugly, but precocious, with a decided flair toward religious mysticism. When she was about twenty her father tried to force her into a marriage, but she escaped and later, upon

the death of her father, sued her stepmother and was awarded all her father's property. From then on, her activities included admission to a convent where she gathered followers, the founding of an orphan home for girls, accusations of cruelty to her charges, flight, a period of delight among the heretics of Amsterdam, an attempt to establish a community house for her disciples on the island of Nordstrand in the North Frisian Sea which involved her and deCort in financial difficulties ending with his premature death in prison, another flight, hostilities with the authorities of Husum, where she set up a printing press, then refuge by the eccentric Colonel LaCoste followed by a quarrel during which he formally accused her of sorcery in 1679, another flight, and concealment until her death in 1680.

She was a second-rate prophet of Quietism which spread over the religious life of Europe during the latter part of the seventeenth and early part of the eighteenth centuries, gaining converts among both Protestants and Catholics. In the "Encyclopaedia of Religion and Ethics," Quietism is defined as "the exaggeration and perversion of the mystical doctrine of interior quiet." Its doctrines were passivity, the surrender of the soul to God once for all in one act, never to be repeated, and an altruistic love of God without hope of reward or fear of punishment. Antoinette's system was personal; she was "the bride of the Spirit," the "woman clothed with the sun," the "channel of revelation." She taught that the "human nature of Christ was dual, and one part was liable to sinful corruption; similarly every man has a dual nature, one part being distinctly good; as the will is entirely free, any one may throw the balance on the right side and obtain perfection here." Seven volumes of her works were published at Amsterdam in 1687 and an English transcript which appeared in London in 1699 had some influence in Britain. It is recorded that in 1661 at Lille, one of her pupils confessed, "The Devil gives them a Mark, which marks they renew as often as those Persons have any desire to quit him. The Devil reproves them the more severely, and obligeth them to new Promises, making them also new Marks for assurance or Pledge, that those Persons should continue faithful to him." This mark or "seal of Satan," on the body, was supposed to be almost positive proof of the identity of a witch.

When Madame Bourignon was in Holstein, Swammerdam wrote to her about his incertitude and as a result of her advice, he resolved to discontinue work on mundane enterprises and to try to "make his peace with God." However, he continued his studies, especially those on bees. In fact he was perpetually examining, dissecting, describing and drawing, from early morning through the blazing heat of the day until afternoon, with the result that his eyes became weakened from constant use and his health impaired from such confinement. In addition he was divided mentally between his impulse to investigate and his desire to devote himself to God. Macgillivray states that Swammerdam, after finishing his work on the structure of bees, was filled with remorse and gave the manuscript to a friend, regardless of its future. At another time he determined to devote the remainder of his life to the "cultivation of Christian piety," in which Madame Bourignon encouraged him, and with this in mind, tried to sell his collection, applying to Thevenot and Stensen to find purchasers. Stensen advised him to embrace the Catholic faith and come to Florence, promising him his aid in inducing the duke to buy it, but to such an offer Swammerdam was deaf. It was about this time that he arranged and catalogued the specimens in the museum.

In 1675 his history of the Ephemera was published, undoubtedly with fiscal

help from some one, perhaps his father, and upon approval from Madame Bourignon. This completed, he resolved again to lead a religious life and went to Holstein to consult Madame Bourignon personally. At that time the Lutheran ministers were making things hot for Antoinette and she prevailed upon Swammerdam to go to Copenhagen and petition the king of Denmark for permission to live in his kingdom. This he did in company with another disciple on March 25, 1676. The Danish king, however, refused to welcome Antoinette, and Swammerdam returned to Amsterdam on June 16 and found his father quite out of patience with his late behavior. Then his sister, who kept house for them, married and his father deciding to live with his son-in-law, Swammerdam found himself without a home and with an allowance of only 200 florins. The next year his father died leaving him heir to enough property for his support, but he became involved in disputes with his sister over the division of the property, and this together with religious worries ended in an attack of malaria with complications, which lasted three months and from which Swammerdam really never recovered. He made his will on January 25, 1680, leaving to Thevenot all his original manuscripts and drawings, which were at that time in the possession of Herman Wingendorp, of Leyden, to whom they had been sent for translation into Latin. His property he willed to Margaret Volckers, one of his executors and wife of Daniel de Hoest. He died February 17, at the comparatively early age of 43 years.

Swammerdam's "General History of Insects" deals at length with insect transformations and the erroneous ideas of the celebrated Harvey, discoverer of the circulation of the blood, whose knowledge of development had been obtained from the study of vertebrate embryos. Harvey said that insects were generated by chance, which aroused Swammerdam's disgust, and he combats this and other mistaken notions of Harvey at great length. Both the "General History of Insects" and the "Ephemera" were later incorporated with the "Biblia Naturae."

His "Biblia Naturae" was not published until 1737–38 and the manuscripts had a precarious and curious history. Thevenot, to whom Swammerdam had willed them, attempted several times to secure them from Wingendorp through Dr. de Hoest, but Wingendorp, who was poor, and not altogether honest, tried by various pretexts to claim ownership. Finally a suit was instituted which Thevenot won in 1682. After Thevenot's death they were bought by the painter Joubert, whose heirs sold them for fifty French crowns to the anatomist Joseph du Verney, who neglected to do anything with them. Finally, Boerhaave, the distinguished Dutch physician, clergyman, student of botany and chemistry, hearing that they still existed in Paris, asked his friend William Sherard, who was going to visit that city, to look into the matter for him. This Sherard did and Boerhaave, who wanted Holland to have the honor of publishing them, succeeded, after some help from influential friends, in purchasing them in 1727 together with the drawings, for 1,500 French florins. As a result, Swammerdam's works were published in two folios in 1737–38, illustrated by fifty-three plates and accompanied by a new Latin version by Gaubius. In 1758 Hill's English edition was published.

Swammerdam's classic "Bible of Nature" includes detailed accounts of the life-history and anatomy of the bee, the gnat, the ephemera, the dragon-fly, gall insects, the water-flea, the snail, the frog, etc., accompanied by marvelous drawings. It contains many original and accurate observations and refutations of the mistakes of previous writers. Miall discusses at some length Swammerdam's work on the bee, the snail and the frog

and praises it highly. In fact Swammerdam's work has never lacked admirers. Wheeler in his recent translation of Réaumur's "Natural History of Ants" states that Swammerdam was the first to prove that "The common ants of northern Europe do not harvest and store seeds."

Swammerdam was thoroughly familiar with his subject and its literature and the work of Ray, Redi, Malpighius, Lister, Leeuwenhoek, Muffett, Harvey, Goedaert, etc., often calling attention to the mistakes of these authors. He spent little time in rehashing the work of ancient writers and stuck closely to his subject, although at times digressions and sermonettes are quite apparent. Frequent mention is made of God and His works, showing Swammerdam's religious nature, and the following quotation indicates how deeply he felt about such matters. "That vulgar opinion, more worthy of brutes than of rational beings, which ascribes the birth and growth of animals to putrefaction and chance, is diametrically opposite to sound reason, and favours rankly of atheism. It has not even the least shadow of experiment or observation to support its truth; but is founded altogether upon sloth, prejudice, stupidity, and error; all which is the more obvious, as in the smallest animals we constantly every where find as much order, contrivance, beauty, wisdom, and omnipotence in the Great Architect, as are shown in viscera or bowels of the largest animals."

In his classification he used developmental characters while his contemporaries utilized superficial, physiological and morphological ones. As a result, scorpions, spiders, and centipedes according to Swammerdam fell into the first of his insect orders because, like the lice, their development was direct and without transformation.

It is difficult to improve upon Miall's estimate of Swammerdam—"That he offered the first scientific account of those transformations which had hitherto been so anomalous and perplexing; that he gave a powerful impulse to the comparative study of animal structures; that he did something for the improvement of zoological system; that he illustrated by a series of examples admirably worked out that method of studying structure and life-history by means of concrete animal types, which still holds its ground as the best form of elementary instruction in biology, and that he made important contributions to experimental physiology and embryology."

Swammerdam was an excellent technician, unequalled in his day. According to Boerhaave, he had numerous lenses and would proceed from one to another. His dissecting instruments which he used so skillfully consisted of fine scissors, knives, lancets and style, some of which were so fine that they had to be sharpened under a magnifying glass. His drawings have always excited admiration, and justly so, as one can see by the few examples that accompany this account.

It is strange that such an independent thinker and investigator as Swammerdam should have fallen so completely under the influence of Madame Bourignon, who from all accounts was positively unpleasant to look upon and erratic, miserly and contumelious to boot. However, Swammerdam was brought up on the Bible as nearly all Dutchmen were, and religion occupied a large share of his thoughts. And although Antoinette Bourignon may have been everything that has been written about her, the fact remains that she had a respectable following at times, due either to the intellectual or emotional appeal of her ideas or her personality or both. Perhaps Swammerdam was attracted by her independence in religious matters. For after all she was really revolting against current and commonly accepted interpretations which of course

THE

BOOK of NATURE;

OR, THE

HISTORY of INSECTS:

Reduced to diſtinct CLASSES, confirmed by particular INSTANCES,
Diſplayed in the Anatomical Analyſis of many SPECIES,

AND

ILLUSTRATED with COPPER-PLATES.

INCLUDING

The Generation of the FROG, the Hiſtory of the EPHEMERUS, the Changes of FLIES, BUTTERFLIES, and BEETLES;

WITH THE

Original Diſcovery of the MILK-VESSELS of the CUTTLE-FISH, and many other curious Particulars.

By JOHN SWAMMERDAM, M. D.

WITH

The LIFE of the AUTHOR, by HERMAN BOERHAAVE, M. D.

Tranſlated from the DUTCH and LATIN Original Edition,

By THOMAS FLLOYD.

Revised and improved by NOTES from REAUMUR and others,

By JOHN HILL, M. D.

LONDON:
Printed for C. G. SEYFFERT, Bookſeller, in DEAN-STREET, SOHO.

MDCCLVIII.

PLATE I.—TITLE PAGE OF THE HILL EDITION OF SWAMMERDAM'S "BIBLIA NATURAE"

accounted for her unpopularity with both Protestant and Catholic professional defenders of the faith. In a way Swammerdam was simply extending his zoological habit of thought to matters of theology, and one should not deny him this right. At times he may have been torn between the love of his work and the idea that such ambition was sinful, but as he continued his research in natural history, one is warranted in assuming that the urge to express himself scientifically won out, and the sermonettes in his "Biblia Naturae" may have been his way of justifying the work. Whatever Madame Bourignon's influence may have been, Swammerdam did not, like Botticelli under the influence of Savonarola, burn his drawings and for this posterity should be thankful.

During Swammerdam's lifetime, far-

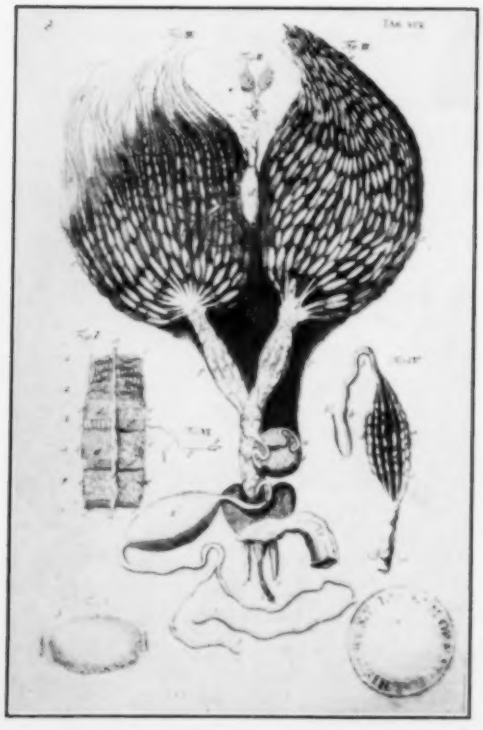

PLATE III.—PLATE XIX OF THE HILL EDITION OF "BIBLIA NATURAE"

FIG. I, THE BEE'S HEART; II, OVARY OF BEE; III, OVARY MAGNIFIED; IV, OVARY OF WASP; V, EGG OF A BEE; VI, POISON SAC OF BEE.

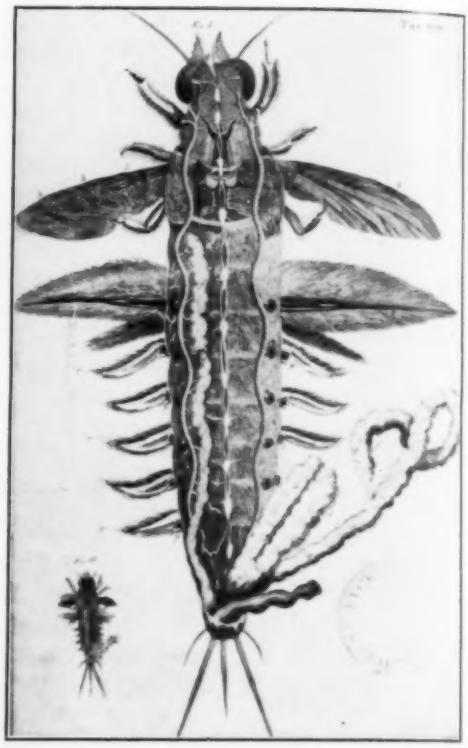

PLATE II.—PLATE XIV OF THE HILL EDITION OF "BIBLIA NATURAE" ENTITLED, "A DISSECTION OF THE WORM OF THE EPHEMERUS."

reaching political and economic changes took place in the Netherlands. The end of the Thirty Years' War in 1648 found the provinces almost at the height of their prosperity, and a few years later their trade was almost five times larger than that of England. France was dissatisfied because the Netherlands had broken faith with her, and England was jealous of Dutch affluence. The politicians of the seven Dutch republics wrangled among themselves for power, and foreign politics was neglected. Then came the Anglo-Dutch war of 1652, provoked by England, Cromwell's navigation laws which seriously crippled Dutch trade, and the loss of Brazil to the Portuguese. Failing to strengthen their federation and to improve their military and political organization, the

Netherlands when they were attacked a second time by England, lost more trade, their North American colonies and their maritime supremacy. London became the chief commercial city of the world and Amsterdam declined. Then came a tariff war with France, imitated successfully by other nations, all to the Netherlands' disadvantage, until in 1672 they were encompassed by foes abroad and threatened by enemies at home. Disunited and unprepared the provinces were attacked by England again and invaded by France, with the result that they went to pieces completely and were saved only by foreign help and by the people rising against the oligarchs who were responsible for the maladministration of the war and for their hardships.

When Swammerdam died, the Netherlands were poverty stricken, trade and industry were disabled, debts had piled up, much low-lying land had become unproductive as a result of the sea-water with which it had been inundated, and the nation was a second-class power. It does not seem to be recorded whether Swammerdam took any interest in political or economic affairs, or not. As a scientist and ordinary citizen he was occupied by his own affairs and probably content to allow the destiny of the country to remain in the hands of the professional politicians and capitalists. He had domestic worries; he was frequently sick and at times in need of money; he thought deeply upon religious matters, and was unhappy; he thought deeply and worked independently in natural history and was a great biologist.

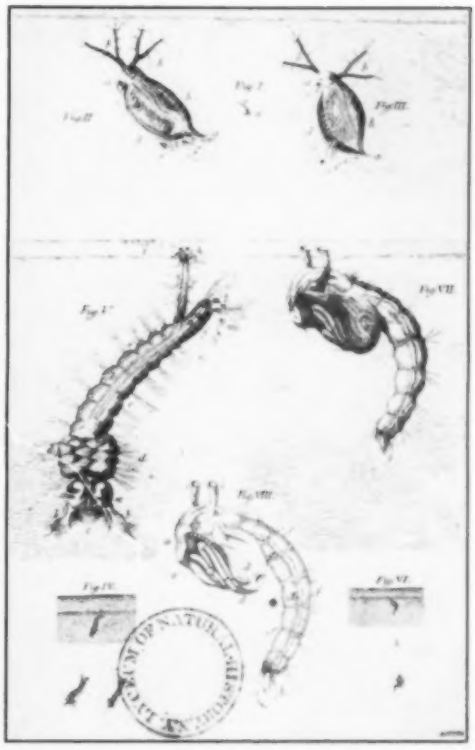

PLATE IV.—PLATE XXXI OF THE HILL EDITION OF "BIBLIA NATURAE"
FIGS. I, II, III, "THE HISTORY OF THE ARBORESCENT FLEA." FIGS. IV TO VIII, "A SHORT HISTORY OF THE GNAT."

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NIGERIA

By Professor A. S. PEARSE
DUKE UNIVERSITY

NIGERIA is a rich country which contains eighteen million people; about one tenth of the population of Africa. It exports palm oil, peanuts, cocoa, hides, cotton, rubber and is quite unhealthful, the climate being hot and humid. Malignant malaria is prevalent and is often followed by blackwater fever. West African yellow fever is usually sporadic among white people, but often fatal. Plague is continually present in the south. Filarial worms, chigoe fleas, ticks, sand flies and other parasites at times make life very disagreeable. In the south diseases carried by tse-tse flies exterminate most large animals, and in many districts human sleeping sickness is endemic. In the drier northern country toward the desert and in the highlands of the Bauchi Plateau large game abounds in many localities and cattle and horses are kept by the natives. Notwithstanding the hardships which attend daily life, Nigeria is an interesting and charming country. It is well governed by a hardy, hard-drinking, gentlemanly and competent little group of British administrators. It is peopled by primitive, cheerful natives, who have an aged but crude civilization. It contains many interesting plants and animals.

Nigeria is divided into six rather clearly defined climatic and vegetational zones, which cross the country from east to west. (1) Along the coast is a series of lagoons, which are bordered by mangroves and other plants that live in brackish water. (2) The freshwater swampy zone supports rather open for-

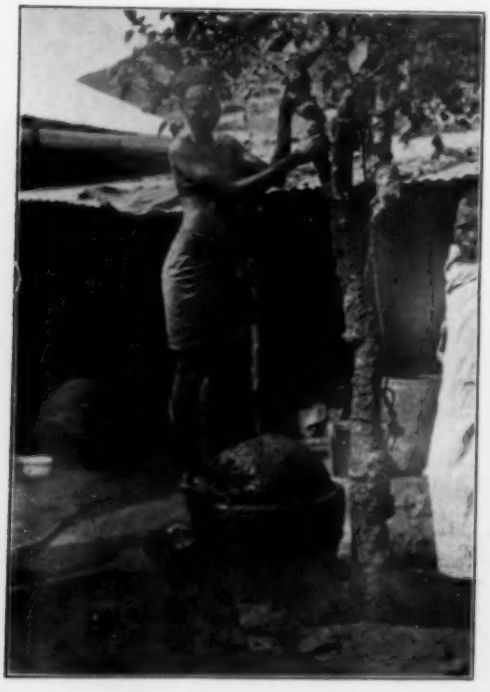
PALM WINE COLLECTORS

A PALM WINE COLLECTOR

ests which contain some valuable trees and, among other products, yields fibers, poles, thatch and some timber. (3) The rain forest, or moist tropical evergreen forest, contains a great variety of trees which are often lofty (over 150 feet) and buttressed. The trunks and branches are covered with epiphytes. Here grow mahogany and other valuable woods. The oil palm, *Elaeis Guineensis*, yields more wealth than any other plant in Nigeria. (4) The monsoon, or mixed deciduous, forest averages about 150 feet in height. It persists where there is a well-defined dry season, during which many of the trees shed their leaves. (5) The savanna is dryer. It consists of scattered trees with twelve-foot guinea grass between. The grass is burned over each year at the beginning of the dry season. (6) The steppe is characterized by thorny shrubs, euphorbias and certain trees. In the north it merges into a bare, sandy desert.

A PALM WINE COLLECTOR

In 1926 the writer worked with the International Health Board in Nigeria and made certain observations on plants and animals which may be of interest. Three months were spent in and near Lagos, on the coast. Here the mangroves, estuaries, rivers and rain forest were studied from July to October. During six weeks at Ibadan animals in the guinea grass were observed, and short trips were made to Oyo and Ife, where there is a luxuriant monsoon forest. In November and December two weeks were spent at Kano, on the edge of the desert.



TREADING OUT PALM NUTS FOR OIL

The Lagoons along the Coast

The lagoons and estuaries are lined with mangroves. On the roots of these plants live crabs and climbing fishes. Among the branches squawking birds and monkeys move about. The water teems with fishes and shrimps. Traps and nets set by the natives are seen everywhere. Dug-out canoes ply back and forth. Tse-tse flies are a great pest

PALM WINE DRIPPING INTO A CALABASH FROM THE CROWN OF A FALLEN PALM

LOADING COCOA

DRYING COCOA

in many localities, particularly along the rivers and in the shade of the mangroves.

The Swamp Forest

These forests consist of plant associations that are permanently submerged in freshwater. They are the home of two piassava-yielding palms, *Raphia Hookeriana* and *R. vinifera*. In addition to supplying the natives with fiber, their leaf stalks are used as poles for propelling canoes, the leaves as thatch, the macerated nuts for stupefying fish, and the stems are tapped for "tombo," or palm wine.

As one goes in a canoe through the swamp forest squirrels and monkeys scamper about in the trees. The ponderous Nigerian toucans squawk and beautifully iridescent little kingfishers sit motionless on the branches which project over the water. The beauty of everything more than compensates for the tse-tse bites endured.

The Rain Forest

The rain forest grades more or less insensibly into the swamp forest. It consists of gigantic broad-leaved trees, palms and other vegetation which make a continuous leafy canopy. Epiphytes are common and in favorable situations cover the trunks of trees completely. Some of the largest trees in the world are found in these forests. Many of the trees are buttressed.

Near Lagos the natives find rich soil in forest clearings. They raise cassava and such fruits as oranges and papaya.

CRACKING PALM NUTS FOR OIL

There are no large animals in Southern Nigeria on account of the tse-tse. The etu is a little deer (*Neotragus pygmaeus* Gray), about as large as a rabbit, which browses in the forest at night. Lemurs (*Perodicticus potto* Geoff.), lizards, snakes and chameleons lurk among the branches of the trees. Evil-smelling civet cats (*Atilax paludinosus* G. Cuv.) and genettes (*Genetta tigrina pardina* Geoff.) hunt in the underbrush at night. The former are very fond of land crabs; the latter prey mostly on mice and are slender, vicious creatures—supple and sinuous.

Rodents are abundant everywhere and, as there is little other fresh meat to be had, are much sought after by the native Yorubas for food. During the day several species of squirrels run about in the trees. In grassy open spaces a striped mouse and a pigmy mouse are found. These two species also occur in the savanna farther north. At night more than a dozen species of mice and rats are active. The large gambian forest rat (*Cricetomys emini* Wroughton) lives in burrows. It has loose cheek pouches for carrying food and is a great pest in the peanut fields. The most curious of the rodents is perhaps the gigantic "cut-grass" (*Thrynomys swinderianus* Temm.), which has a stubby tail and is shaped somewhat like a guinea pig.

A GIANT COTTON TREE WITH BUTTRESSES

ETU DEER

Along the forest trails at intervals the nests of the social weaver birds are conspicuous. The parrots are not so noisy as those in South America, but there are other birds which keep chattering. In the evening a little bird sings a plaintive and sweet but monotonous song which reminds one of the American chickadee. Giant goatsuckers roost in the trees during the day and are often seen on the trails at night. A favorite roosting place of the large fruit bats is along the midribs of cocoanut palms.

Ants are found everywhere. There are travelling species which have no permanent home and a variety of spe-

RUBBER TREES

cies which live in underground burrows. One species builds a nest by fastening the living leaves of shrubs together into a neat globe. The forest termites do not build very large nests, but their architecture often takes fantastic forms. One species builds little towers like mushrooms in the deepest shade of the forest. The Yorubas do not disturb these towers because they firmly believe them to be the homes of devils.

The open places and thickets along the borders of lagoons and streams are favorite resorts for land crabs. In such situations civet cats, storks and great monitors hunt. One monitor examined by the writer measured forty-six inches in length. It was kept in captivity for a couple of weeks and proved to be a savage creature, which ate two or three crabs daily. My native hunter maintained that monitors become quite tame if kept in captivity for a long time. Among the larger animals in the Nigerian rain forest are the elephant, dwarf buffalo and deer. Few of these larger

WEAVER BIRDS' NESTS IN PALMS

animals were seen by the writer, as he was in tse-tse fly country.

The Savanna

The "guinea grass" grows for hundreds of miles through Nigeria. It consists of several species of plants which stand twelve to fifteen feet in height. Among these grasses grow scattered trees which become fewer as one travels north. In the Guinea grass live many game animals—elephant, hartebeest, giraffe, rhinoceros, lion, cheeta, hyena and hare. At the beginning of the dry season the grass is burned over. During December and January Nigeria is full of fires. After the burning, the hunting season begins and game animals commonly take refuge in little patches of grass which have escaped the fires or in the fringes of forest along streams. In the Guinea grass natives farm mostly on virgin soil, new areas being broken up after each annual burning over. The crops are chiefly maize, cassava, yams and fruits.

The Guinea grass is a monotonous habitat and appears on casual observation to be scantily populated with animal life, but besides the large game animals it shelters many small rodents

CASSAVA GOING TO MARKET

A CASSAVA TWIG IS STUCK IN THE GROUND, WHERE IT TAKES ROOT AND SENDS UP SHOOTS

and birds, such as bush fowl, which is much like a grouse, and wild guinea fowl. The termites which build mounds on the savanna near the Niger River at Jebba construct fantastic towers which remind one of church spires and are fifteen feet in height.

CHAMELEON

Swarms of foraging ants are frequently met with in the Guinea grass. The commonest species is a small dark ant which robs termites' nests of their young. There is no honor among thieves! The fly sits waiting beside the roadway of the robbers. With a favorable opportunity it pounces on the laden caravan and throws an ant with its burden to one side. It then takes

the termite away from the ant and sucks out its juices.

The Steppe and Desert

At Kano the writer had an opportunity to see some of the life in the desert. The vegetation consists of euphorbias, grasses, acacias and other shrubs. There are few types of animals—gazelles, sandgrouse, rats, mice, jerboas, shrews, hedgehogs, crows, buzzards and other birds. There are no proper house rats, but the native dwellings shelter shrews and jumping mice. There is a species of Gambian rat which is lighter colored than that in the forest. Caravans of camels, donkeys and bullocks are continually arriving from, and departing for, the desert. At the beginning of December they were mostly laden with peanuts and goatskins from the north.

On several nights trips were made along the trails with a jacklight and a number of hedgehogs were captured. A hedgehog is very entertaining. When handled it folds its head and legs into the pit of its stomach, pulls its skin up to cover these appendages, and contracts a muscular puckering string which encloses them in a bodily bag. Thus the hedgehog becomes a spiny ball which, to mix a metaphor, is a hard nut to crack.

A HEDGEHOG

BOY CARRYING CASSAVA ROOTS

TERMITE MOUND

FOREST TERMITE NEST

A MONITOR FORTY-SIX INCHES LONG

Nigeria is to-day an undeveloped and in some respects a primitive country which promises rich commercial returns in the future. It still offers good game hunting and will probably continue to do so for some time, for great stretches north of the Niger receive little rain and will long remain scantily populated. For the naturalist there is much of interest. In another paper the writer expects to give a short account of the native people of Nigeria.

THE EVOLUTION OF THE PARENT

By Dr. NATHAN MILLER

CARNEGIE INSTITUTE OF TECHNOLOGY, PITTSBURGH, PA.

THE original social relationship is that of mother and child. It is based on a deep-rooted organic foundation, which is the leverage point sustaining the whole edifice of the evolutionary process. This intimate physical bond recalls eons and millennia through which the spark of life that lay wallowing in primeval slime was nursed into the erect, dimly conscious mammal that writes articles about himself. The continuum of this epic process from the evolution of organisms into the social method of development is furnished by this same attachment of mother to child. The kernel of all succeeding social systems and relationships lies in the mother. The succession of generations of animals and the preservation of the species hinges on the maternal arrangement. Somewhat similarly, society with its heritages of tradition and experience takes its rise in this same bond.

There is no group that primitive which does not give evidence of the esteem with which the mother is surrounded. In the rudest and simplest of hordes there stands out a figure of the mother above the general vagueness of social outline. Even where the wife or woman is abjectly degraded in status, the mother is always recalled with deep expressions of sentiment. Livingstone was struck by this fact in the course of his explorations in Africa. In a moment of sudden terror or fright, the otherwise calloused native would cry out the name of his mother. All other social attachments were transitory and spasmodic. The struggle for existence was too ruthless and pressing. There were none of the "noble" sentiments that can be cultivated except that most patent and primal concern for and adoration of the mother.

The reasons are not far to seek. The physical attachment of the human child to his mother is long-protracted. Born very helpless and impotent, without the claws, teeth, fur or the keen senses of the animal, its existence is bound up irremediably with that of the mother. In the simpler societies, in addition, suckling is a long-continued affair. This is due to the lack of animal or plant food adapted to the infants' use. In fact, the child is often mature physically before the lactation period has ended. Among the Papuans, for example, Hagen on one occasion observed a small rascal run up to his father, snatch the cigarette from the father's lips, puff away and shortly thereafter resume his interrupted meal at his mother's breast. In the Bismarck Archipelago, similarly, youngsters of four years have been seen indulging in the same mixed diet.

The child must thus remain a veritable appendage to the mother through a longer course of years than we are accustomed to. When the mother is at work in the fields, the child is securely strapped to her back. Mother-love is quickened and more enduring and the child's existence is part of that of the mother's. Should she succumb during the child's early years, the child is buried with her. The natives of the D'Entrecasteaux Islands in Melanesia bury such a child alive at its mother's breast and stamp down the ground above it. Nothing else is possible where social structure is still inchoate.

Yet the native genius of all races has

idealized this attachment to the mother in endearing terms. As in all folk expression, the common life experiences of the group are colored and spontaneously expressed. Thus, among the Maoris of New Zealand the native poetic talent has drawn up this distich sung to the child:

> My necklace of scented moss;
> My necklace of fragrant ferns;
> My necklace of odorous shrubs;
> My sweet-smelling locket of Taramea.

The highest traits of the American Indian character were aroused, undoubtedly, in his relation to the child. The Chukchee of the Siberian wastes treats the child with great tenderness and uses the affectionate term of "little eggs" in common parlance.

However, maternity appears to be quite a trivial incident in the "lowlier" stages of societal development. There is very little hubbub or perturbation of expectancy and preparation surrounding the advent of the child. Usually the expectant mother is kept to her laborious stints up to the last days. At all times rationalizing justifications can be easily supplied for current practices, or mores. (This, even where foreign offices, official spokesmen and professional historians have not yet appeared.) So, according to Hooper, the Coahuila Indians of California believed it best "that the expectant mother have plenty of work to do during the nine months so that the child may be industrious and strong." Consider the Fijian woman who has been known to go out in the morning in an advanced stage of pregnancy and return in the evening with a load of firewood on her back and a newborn child in her arms. Nansen relates that on one of his journeys an Eskimo woman was overtaken with labor. The husband thereupon nonchalantly dozed off. When awakened he expressed his satisfaction "by smiling at his spouse and saying 'Ajungilatit' (Not so bad for you)."

The ruthless severity of nature is not, as yet, tempered or insulated by an economic and social system sufficiently developed and evolved. The individual struggle for existence annihilates in time of need and distress the budding social sentiments including this mother feeling. Infanticide — apparently a breach in the ways of a group—may yet become so usual as to amount to a common usage or folkway. Among the Kuni in Africa, infanticide is very common. "There is not a woman who has not killed one or several children. It is a cruel custom which all the women have to follow because, as they say in kuni, 'kufumai tsi koakoa doka' (such were the customs of our ancestors)." In the islands of the Torres Straits, in fact, the practice is arranged for before the birth of the child. The Polynesian women are known to do off with four, six or even eight children during their lifetime. The reason most often given in explanation of this is the shortage of food. Ellis says of the Polynesians that they are not willing to cultivate a little more ground or undertake the small additional labor necessary to support offspring during the helpless period of infancy.

Even when the child is spared it is open to intermittent bursts of cruelty and savagery upon the part of the parent. These are incited, again, by the exigencies of a harsh, bare environment which can not, as yet, develop the finer sentiments into a stable consistency. Personal vexation and animal discomfort caused by the child is often sufficient provocation for inciting the mother into violent action. Momentary impulses still rule. The Abipone mother may be accustomed to bewail the death of a child through disease, yet she does not hesitate to dash out its brains when food becomes scarce. The Australian mother in her bursts of affection "buries her face in the neck of the child and draws in a long breath through her nostrils: in

fact, she smells it." But the bitter, sterile environment withers such sentiment. Even child cannibalism is often a horrible aftermath, as in Samoa, where Turner witnessed such an occurrence during a great scarcity caused by a gale. "If a child was seen out-of-doors someone would entice it by holding up something white and calling the child to get a bit of cocoanut kernel and so kidnap it . . ."

Intolerable outbursts of temper, alone, are sufficient to work this grievous result. As the rule there has not yet been any development of a system of discipline and punishments on these social levels. The children are accustomed to the utmost wilfulness and obduracy and given full rein in their conduct. Yet in a sudden streak of passion or vexation (as has been described of the Sandwich Islanders), a mother is liable to sacrifice the child on a trivial incitement. For example, some have done this simply to pique or retaliate against their mates.

Certainly the maternal sentiment, though deeply embedded, has an irregular mode of expression. The attachment is purely animal-like. This may account for its fitfulness. Extreme fondness is often displayed toward the young animals with whom the women may play for hours at a time. Many pertinent and well-substantiated cases are at hand to illustrate. To choose one: in Guiana, tame animals, particularly young apes, are the pride of the women. They are nursed and tended exactly as though they were children and become so attached to the women that they dog all their steps and movements. Like evidence comes to us with respect to the now-exterminated Tasmanians, the old Hawaiians, Patagonians, and others.

These facts are abhorrent and disagreeable to the sensitivities and sympathies of a "civilized" people who are supported by a developed, elaborated social system. The eulogizing of mother-love is, to be sure, token of the depths which this feeling plumbs, of the intimacies burned and seared indelibly into the blood and bone of the child of a highly "cultured" group. Nevertheless, in the ruder, simpler levels where the struggle for existence itself is bereft of the safeguards of a developed economy, sentiment can not survive stark reality. As long as food is plentiful the child has all latitude of freedom and has showered on it unbelievable indulgence and kindness. But where each individual must grub for himself the rôle of the mother becomes subordinated to that of the individual seeking to sustain life itself. Civilization has erected upon this foundation an economic and social superstructure, which is our "culture" and which has woven subtler bonds about the concept of the "mother." Custom has directed its expressions into longer-visioned ideals and deeper values or at least permitted of a more constant, wholesome expression of this eternal tie.

Turning now to an investigation of the development of the concept of the "father," we find a similar line of approach. Only here the connection of father with child can not be said to have that firm organic tie possessed by the mother. The bond is extremely tenuous, uncertain—and for long ages—an entirely misunderstood and problematical one. The notion of the male as procreator is extremely hazy and dubious, if not entirely lacking in the stock of ideas and their social manifestations among primitive groups. Nor is it to be wondered at. An adequate realization of paternity had to wait upon a large accumulation of experience and observation. Particularly was this evident in the earliest forms of society where children could be bound up only in a general way with the mother. All social organization as a result was extremely vague and disordered. Under

the dominion of the natural appetites and urges there was little impetus to discriminate and select the male parent. The whole history of the development in establishing the definite, exclusive notion of the male parent was motivated probably by the necessity of bequeathing and endowing the children with the status and standards of life of the male parent. The nearer we approach the dim region of social origins, however, the closer we touch upon relative promiscuity. Under such conditions the idea of the male parent was naturally non-existent.

Among the most primitive groups of which we have reliable data the attention and interest of the older males is directed not to particular children in that intimate personal sense connoted in the term "father" to-day. Instead, the older males give sporadic care to the younger—alternating between extreme indulgence and frightfully barbaric cruelty. Indeed the child is a plaything and flatters his parent as a toy model. Primitive communalism reigns and parental oversight is carelessly diffused. The first clearly "social" division born of human association in groups was probably between generation-groups, old and young. Here the differences in muscular strength and power are obvious. The strict rôle of the parent is borne on these stages solely by the mother.

As the ideas surrounding the "father" develop, in some such fashion does social organization become elaborated and more settled. The first employment of the term was not to establish and describe the genetic connection of paternity but rather to express the economic status of the male as regards the young immediately about him. Now the male looms up as the preponderant contributor in the struggle for existence, as compared with the woman. In this gradual transition there has occurred the most significant, telling step in social evolution. The male eclipses the woman in the development of society primarily because of his superior economic contribution to the life which came in with the pastoral era. The domestication of animals fell uniquely upon the men and insensibly metamorphosed most social notions, including that of parentage.

This revolution occurred only in the nature of all social forces—slowly, lumbering and haltingly progressing. The effect was to render the man all-powerful and despotic and to thrust the woman into the status of a slave or chattel-dependent. The children as well fell into the position of property, and the "father" became a mode of expressing ownership rather than parentage. Thus, among the Ewe-speaking peoples in West Africa, neither of the words now used to express "father" bears any relation to the act of begetting. "They do not mean 'he who begets' but 'he who owns' and 'he who maintains.'" The native language contains the word "fofo," which is an older term for "father." It is derived from the verb "fo," "to support, maintain." Among the neighboring Yoruba the term "baba" means lord, master, great person or father. In East Africa, similarly, we have it on good authority that the owner of a woman is regarded as the owner and father of her children, whoever the real progenitor may be. In Siberia, also, the Yakuts had no name for "father" which admits of a natural and simple explanation, like the word for "mother." The word for "mother" means "procreatress," but the word for "father" should be translated "older man."

The climax of this line of development is reached in the full-blown patriarchy where the traditional patriarch or "overfather" stands with over-weening prestige, power of rule and ownership of women and children.

The narrowing down of the term "father" to the actual progenitor was

the direct reflection of man's experience probably with the breeding of animals and the simultaneous growth of knowledge. We can not claim a continuous or exactly concurrent series of events in the development of social concepts throughout the world. We can state with some degree of certainty, however, that paternity is a notion of comparatively recent origin and the fruit of countless centuries of progress in the adjustment of men to life in society.

As society progresses, thus, to the attainment of the knowledge of the domestication of animals and plants, the male dominance grows. The older mother régime had never been tantamount to a system of rule by the women, as has often been asserted. There was never more than a vague adherence to a mythical original mother along with an apparent laxity in organization, absence of tabus and lack of differentiation of the individual in the usual concerns of life. Cohesion was about this actual or legendary female ancestor. With the advent of the patriarchal reign there arose a persistent motive toward social division and the creation of various levels or status in life. Invidious distinctions arose. Children acquired added worth and benefit to the father. Their economic contribution to this struggle for standards in group-life was magnified. So, also, does their value increase as caretakers of the departed parental ghosts which hover beseechingly and dangerously about the hearth. For such reasons it becomes of supreme importance to have children and to identify them irretrievably as one's own.

This truly social note is betrayed in many lands in the ceremonies whereby the "father" accepts, identifies or lays claim to his children. The exact form this assumes is queerly redolent of the traditional, more firmly established parental relationship—that of the mother. This is illustrative of the ordinary tendency in society of the ancient usages and beliefs to hang on tenaciously beyond the day of their effectiveness, borne along by the great weight of the customary and indifferent past of the group-life. The old never dies totally in society. Thus, the Rhodesian "father" ties a string of beads on the child's wrists and legs, and takes it and nurses it in his arms. In the Celebes Islands, the mode is more striking. There the father bites off the navel-string of the child to indicate approval of the child as his. In the D'Entrecasteaux Islands, the rapprochement between father and child (for such it may be called) takes place through the consumption of a common meal. This has always been a popular method of cementing relationships not eminently obvious in the nature of things. The father and the child sit down to a meal prepared particularly for them. Others may look on, but only these two may partake. It is quite evident that the mother never was moved to employ such typical ceremonial fictions to establish *her* relation to the child.

For many centuries the notion of parentage was thus a fragile, uncertain bond. The attachment to the child was preeminently fixed upon a physical basis. The deep tokens of affection bestowed on the child astound us even to-day, as among the most primitive of peoples—the Australians, the Veddahs, of Ceylon, the Ainu, of Japan, the Fuegians, etc. But all this is irregularly displayed indeed. Privation and want will mean the taking off of the child without the slightest compunction or hesitancy. Contrast with this state of affairs the elaborate and specialized organizations and provisions for the care and instruction of the child of to-day—care and solicitude that are the products of the anxious interest of the parent of to-day.

This striking contrast is explicable only in the light of the interpretation of

social evolution set forward in the above. The child falls into a status and a position of dependence as the group life evolves out of its undiscriminating simplicity and acquires a body of tradition, lore, economic apparatus, tried ways of life and mores. In the early stages examined here the difference between parent and child, especially in the struggle for self-maintenance, was very insignificant. Young and old were alike "children of nature" and as such possessed equal ability to wrest support from the environment. The child left the maternal breast to be thrust directly into the business of life. There was no superior skill that the parent could impart save that of sheer force and brute strength which nature alone could provide. As time passed, the group slowly carried along with it increasingly effective folkways which cut a clear gulf between the parent and the child. In addition, ideals and traditionary experiences become the child's heritage and these are to be received through the parent. Otherwise they are lost forever. Hence there emerges insistent motives for training, discipline and an education that nature alone can not enforce without allowing each generation to start anew in its own way. The tremendous weight of tradition and the zealous, invidious interest of the parent place the child definitely in its position as the heir of the ages.

The mother concept and feeling is transfused and elaborated by this annexing of many-faceted social impulses to the bare urges of the organism. The stress toward equipping the child with the far-flung ideals of one's own station and ambitions in the social scheme reinforces the mother sentiment as described above. Certainly the "father" sinks more complex roots of interest in the child. The motives are very often, of course, of very selfish origin, as the child begins to reflect the wealth, titles, "honor" and worth of one's position in society or the flickering ambitions in the struggle for standards of living. The idea of the relation between parent and child deserves careful study in this light as it is coming to acquire vital and permanently changing significance in the great propulsive sweep of society. Today the suspicion is being voiced that the business of being a parent is fit subject for taking of stock and thorough discussion as the times—and the mores—change so rapidly. The only point at which to start may most profitably be some such examination of the past as here presented.

ARSENIC EATERS

By Professor NORMAN J. HARRAR
COLORADO AGRICULTURAL COLLEGE

ONE of the poisons known to the ancients, one of the weapons of many famous and of many more obscure criminals, one of the allies of man in his war on marauding insects, one of the most deadly of toxic substances—arsenic.

Perhaps it is because of this traditional association of death-dealing properties with the compounds of arsenic that makes all the more striking the contrast afforded by the peculiar habit indulged in by the people called "Arsenic Eaters."

References to this custom in recent publications are usually brief and are frequently obvious restatements of equally brief notations in earlier works. That arsenic eaters live in Styria and eat the poison to improve the complexion and the breathing is the extent to which the subject is discussed. The testimony of J. F. W. Johnston (1855), who bases his remarks on that of Dr. Von Tschudi (1851), and of Roscoe (1860) and perhaps of a few other observers, unnamed, seems to be the chief source for these meager statements. In some respects, the story seems to be assuming the proportions of a legend. Therefore, it is not surprising that doubts as to the existence of the custom should be expressed, and we find in "Chemical Pathology," by H. Gideon Wells (published 1920), the statement that "There is, however, reason to question the authenticity of the reputed tolerance of habitués to arsenic." By numerous experiments, mostly on dogs, investigators have reported that an arsenic tolerance even approaching the reputed doses of the arsenic eaters could not be reached. The obvious conclusion drawn, therefore, is that arsenic eaters do not exist.

References to the arsenic eaters always locate them in Styria, a province of Austria, with Graz as its largest city. Therefore, an inquiry was addressed to the professor of chemistry of the University of Graz. This was received by Professor Scrabal, who referred it to Dr. Fritz Pregl, of the Medicinisch-Chemisches Institut of the university, who is considered to be their best informed man upon the subject of arsenic eating. Dr. Pregl has most kindly endeavored to give a survey of the present situation, in addition to important historical data, and this information, coming from one who is considered an authority in the very place where the custom is said to be common, ought to carry considerable weight. As a result of this correspondence, the writer is able to give a fairly complete summary on this interesting subject and to present some details, not found in previous accounts.

The important and seemingly disputed question is as to whether or not arsenic eating is prevalent, in what we are pleased to call this civilized day and age. To quote Dr. Pregl's exact words in answer to a direct question on this point, "Die Gewohnheit des Arsenikessens ist auch in der Gegenwärtigen Zeit in Steiermark üblich," which translates, "The custom of arsenic eating is common even at the present time in Styria."

Having cleared the way somewhat with this statement, a note on the character of the country, of its industries and of its people is appropriate. The province of Styria is in southern postwar Austria, bounded on the south and west by the provinces of Cariniola,

Carinthia and Saltzburg, on the north by Upper and Lower Austria and on the east by Hungary. The northern and western portions contain the rugged Styrian Alps, cut by rather narrow valleys of four rivers, the Enns, Mur, Drave and Save, all of which eventually flow into the Danube. Lower lands, but of a steep, hilly nature, are found in the southern corner of the province.

With such a topography, it is obvious that the land is not well adapted to agriculture on any large scale, and it never has been extensively used for this purpose. However, the mountains hide a mineral wealth, which has given the people an important industry for many centuries. Gold, silver, lead, iron, coal and other minerals have all contributed their share to this industrial prosperity, but by far the most important and steadiest output has been of iron. There is an interesting tradition among the miners of Styria, which illustrates the point.

When the barbarians from the regions north of the Danube drove the Romans from this province of Styria, then known as Noricum, the Genius of the Mountains, willing to do the conquerors a favor, appeared to them and said, "Take your choice: will you have gold mines for a year?—silver for twenty years?—or iron forever?" The wise ancestors of the Styrians, who had just begun to learn the true relative value of the precious metals, by ascertaining, practically, that their rude swords were an overmatch for all the wealth of the Romans, at once decided to accept iron forever.

The most extensive iron mines are located around the Erzberg (ore mountain) which is said to be literally a mountain of iron ore and ore of a remarkably high grade. In fact, the quality is such that its fame spread and created a demand for it far beyond the confines of the province. For centuries this region has been the source of over half of the iron used in Austrian domains. The more important foundries are to be found at Eisenerz, Vordernberg, Hieflau, Zeltweg, Trafaiach and Neuberg. It is in the treatment of these ores that arsenic makes its appearance, and it is very probable that the entire history and perhaps the origin of arsenic eating is closely related to this industry.

The smoke from these furnaces carries a considerable quantity of arsenic, from which As_2O_3 readily precipitates. In the former so-called Giftkanälen, or poison pipe, this white arsenic collected and because of its origin was referred to as Hüttenrauch, or smelter smoke. This name was commonly shortened to "Hidri" and sometimes another corruption, "Hydrach," was used in speaking of the substance. At regular intervals, it was necessary to clear these flues and this was done by workmen equipped "mit Hammer und Meissel." In order to more efficiently remove the valuable by-product from the smoke and to prevent more completely the spreading of an objectionable substance over the surrounding land, modern equipment provides one or more condensing chambers. It is not purposed here to go into further detail about the process, but the interested reader can find an excellent description in the "Dictionary of Applied Chemistry," by Sir Edward Thorpe. However, it is interesting to note that the workman employed in the removal of the arsenic from these condensing chambers of the modern plant must wear special clothing of leather and protect his mouth and nose with wet cloths. Even with these precautions it is said that only arsenic eaters can perform this task continually.

The principal market for the product has been for the making of arsenical glass and for its legitimate uses as a poison, but considerable amounts have

always been deflected for the purpose of eating. Quantities of arsenic, despite the strictest regulations, still get into the hands of the peasants, and to make the situation more difficult to control, into the hands of itinerant peddlers, who carry on quite a lively, although secret, trade. To quote Dr. Pregl, "Nearly in every farmhouse, or in any case in every second, in upper Styria one finds more or less arsenic mixture." This is not always the property of the owner, but frequently belongs to his horseman, who keeps it in some secret place.

The trioxide of arsenic, As_2O_3, is the form in which the poison is most commonly eaten. However, there is a curious preference exhibited by very many arsenic eaters, apparently for purely superstitious reasons, for a so-called artificial yellow arsenic. This probably is due to the connection the custom has with iron smelting, for part of the condensed material does contain sulfur and has a yellow color. Yellow arsenic, by which term As_2S_3 is designated, is artificially made by melting together arsenic trioxide and elementary sulfur and this product is sold by the peddlers to satisfy the demand. Dr. Pregl reports that upon examining a large number of these preparations, he found at least 75 per cent. unaltered As_2O_3 in every one and that in some cases the mixtures contained as high as 92 per cent. As_2O_3. Therefore, the preparations are falsely named and the preference is a mere fancy upon the part of those who are thus deluded. However, a preference of this sort is certain to be well known to the peddlers and carefully played up to, for they know, as is shrewdly said, "um sich besser bezahlen zu lassen"—for it pays better to suit.

The amount of arsenic which constitutes the average dose and the amount which would be a maximum dose have been variously stated in the literature. Upon this point, which is a vital one to scientists interested in the subject, Dr. Pregl is rather reluctant to be specific, for several reasons. These might be summed up as follows. The habit must necessarily be of a secret nature in these days, the indulgers themselves make no attempt accurately to measure the amount they take and probably because of this, there is no general agreement as to what the exact quantities are. However, he does recall demonstrations given at a gathering of medical men some forty years ago, when real secrecy was not so necessary, in which those accustomed to the poison ate it, spread on bread, in quantities of at least 2–3 g. In fact, this method of receiving the arsenic is still the most common. With his knife, the arsenic eater cuts away from a larger piece that quantity which he estimates with his eye to be the right amount. From time to time, he gradually increases the quantity as nearly as he can estimate it in this crude fashion. Briefly, it is not the nicely calculated dosage being absorbed by the drug fiend, but rather a somewhat variable quantity which through custom has become a part of the daily diet.

The effects of arsenic eating have provoked considerable comment. It is said to improve breathing, to increase the endurance, to fatten the body, to improve the complexion and to lengthen the span of life. All these effects, except the last, seem to be easily discernible in Styria. To quote again, "the respiration and heart action are facilitated and the nutrition improved, the appearance is brightened and the hair of horses and of men made smooth and glossy."

Very striking indeed, are the results of a stopping of the regular administration of arsenic, "then the phenomenon takes place in the opposite way, horses and also men decline, respiration and heart action become difficult, the appear-

ance fails and the hair becomes shedding and shaggy." Dr. Pregl states that he has had on very many occasions the opportunity to personally observe these facts.

A question which naturally arises is as to whether or not the continued indulgence in the eating of arsenic produces ill effects. Upon this point, some writers have stated that a chronic arsenic poisoning takes place, basing their assertions on experimental data. In the case of the people of Styria, it seems that, "even after ten years," no apparent bad effects are discernible. It might be that careful examinations at regular intervals, over a long period of time, upon an individual typical of the group, using known amounts of arsenic, would throw some light on this question. The secrecy under which the habit is indulged makes this procedure rather difficult. In this connection, it seems almost too hasty to draw conclusions about the condition of the true arsenic eaters based on comparatively brief tests on dogs or even men.

Another obvious question which presents itself is as to whether or not any sense of pleasure accompanies the habit. There is no doubt but that no immediate enjoyment, such as the agreeable effects produced by narcotics, is connected with the use of arsenic. However, here again, one is confronted with the possibilities of a habit practised from generation to generation for many centuries. Of course, once the habit has been adopted, a potent factor in its continuance is the intimate knowledge of the disagreeable effects a stopping of the dosage would inevitably produce.

An important reason for the persistency of the custom is its use with horses and so by the handlers of horses. The arsenic is ordinarily administered to the horses on their food, or sometimes placed in the mouth where it slowly dissolves. This very probably serves as an aid to their endurance and undoubtedly improves their wind for work on the steep slopes and gives them a glossy, well-nourished appearance, even after a hard day's work. The handlers who do not feed arsenic are certain to suffer by comparison. Especially is this true in cases where a new man is employed, who is unaware of the fact that his predecessor used arsenic continually, for then no matter how carefully he handles his horses, the symptoms noted above soon appear. A restoration of the arsenic to the diet is the only remedy. In such a situation, it may not even require the threats of an angry employer to decide the course of action.

Attempts to prevent arsenic from reaching the people and to discourage its uses are due in no small measure to the relation it bears to crime throughout the country. Practically all poisonings are done with arsenic and the trials hinge upon proof of its criminal administration. Pausing a moment to consider, it is obvious that the possibilities are unlimited and absolute certainty almost unattainable. Dr. Pregl states, "In a year, I have had to undertake and to pass judgment upon, in legal proceedings, more arsenic poisonings than in all Germany in ten years." The more important reasons for this condition are the ease of procuring the poison, for, if no other source is available, it may be obtained from the peddlers, and the veil of secrecy under which the custom and transfer of the arsenic is shrouded. Hardly less important factors are the intimate acquaintance the people have with the poison, the possibilities of accidental reception and the more or less doubtful value of even proving the presence of arsenic by post-mortem examination. All this tends to create a remarkably difficult situation to handle and it is interesting to speculate how a half dozen typical American criminal

lawyers could manage to make convictions a lost art in Styria.

Lest a wrong impression of this country result from this account, it is well to quote Dr. Pregl again, "It is false to think that the larger part of the population of Styria indulge in the custom of arsenic eating." A great number of the people have, in the course of time, gradually dropped the habit, so that conditions are certainly not as bad as they once were. However, it is true that the custom still is "fairly widespread" among the horsemen. Nor should these people be too readily condemned, for perhaps many of the customs of our country, not even having the saving excuse of antiquity, seem to them to be just as queer and undesirable.

A final query is concerned with the origin of this unique custom. It is not easy to follow the trail back through the centuries, but one or two significant facts seem to stand out prominently. The habit has always been closely connected with the iron-smelting industry; the arsenic has been eaten with the food; it has been commonly given to the horses. Perhaps some observant peasant of the long ago noted an improved condition in horses grazing near an iron foundry and was led to investigate. It is a matter for speculation. The chance ways in which many of our healing herbs and of our most practical remedies were brought into use are equally obscure and the names of the discoverers are unknown. Arsenic eating has a long past—and the beginnings are lost "in der grauen Vorzeit."

METHODS IN THE STUDY OF DOMESTICATIONS

By Dr. BERTHOLD LAUFER

FIELD MUSEUM OF NATURAL HISTORY

IT is a fond delusion of many to believe that ethnology, because it deals essentially with living peoples of the present time, can contribute little or nothing toward reconstructing the cultures and culture movements of the past. What I wish to demonstrate by a few practical examples from the chips of my workshop for the benefit of the younger generation is that it is possible to reconstruct by means of purely ethnological data and methods mental processes and culture phases of the past which can not be reached by historical or archeological methods. I choose my examples from the domestication of animals, because this is a subject of fundamental importance for the history of civilization and but little scrutinized and elucidated by ethnologists.

Our domestic animals can be studied from many different angles—zoological, anatomical, biological, economic, geographical, historical, archeological—and these various sciences have made many excellent contributions to our knowledge of the subject. It is obvious also that only by a combination of the results gained from so many different fields can a satisfactory solution of the problems be attained. Yet the most interesting question relating to our domestic animals has hardly been touched upon, and this is man's relation to them, or in other words the domestic animals from an ethnological point of view. What motives prompted primitive man to go to the trouble of domesticating animals and by what means and by what mental attitude was the primeval process of domestication brought about? To the layman the answer seems easy enough. We hear it almost daily and read it in our school-books that man keeps sheep for the sake of their wool, cows for their milk, chickens for their eggs, swine for the sake of flesh, etc. But all the material advantages which we now derive from domesticated animals are but the effect and result of prolonged activity in matters of domestication, and cause and effect can not be identical. Wild fowl, *e.g.*, do not propagate to a large extent, nor do they lay eggs in great numbers. The egg-laying habit of our chickens, to such an extent that it was of some economic advantage to man, was only developed after many hundreds or perhaps thousands of years of a gradual evolutionary process of domestication. When primitive man first adopted the wild fowl into his household, he could not foresee or anticipate any substantial benefit, no more than the alchemist of a thousand years ago could foresee that his alchemical lore would develop into the science of chemistry in the nineteenth century. Moreover, the utilitarian viewpoint is contradicted by plain observations of present-day conditions. There are, for instance, many tribes in southeastern Asia, Polynesia and Melanesia who keep chickens and have kept them for millenniums, but do not use their eggs or their flesh; there are other tribes among whom the pig is a sacred and sacrificial animal and is eaten but once a year in the solemn act of a religious ceremony. The Chinese have raised sheep and goats for thousands of years, but have never utilized their wool for making textiles for clothing. All East-Asiatic nations keep cows and buffalo, but never milk these and never consume animal milk. Primitive

man is not rationalistic, but emotional, imaginative, impulsive, and it is in vain to look for rational motives in his first contact with the animal world.

Years ago I pointed out that Asia with its European annex is split into two well-defined and sharply contrasted economic camps, the boundary line running along the frontier of China and Tibet. All West-Asiatics, including the Indo-European nations, Semites and all nomad tribes of central Asia, have a highly developed dairy economy, and dairy products, such as milk, butter and cheese, form an important part of their daily sustenance. The entire East-Asiatic world, however, including the Chinese, Koreans, Japanese, Annamese, Siamese, Burmese, Malayans and many peoples of India, do not take animal milk for food and evince a deep-rooted aversion toward it. A Chinese looks upon a milk-drinker with the same dislike as we may feel toward people who subsist on monkeys, snakes and insects. The amazing feature, of course, is not the mere fact that East-Asiatics do abstain from milk, for the natives of the South Seas, Australia, America, etc., do or did the same simply for lack of milk-producing animals, but the point at issue is that the Chinese and their followers adhere to this negative practice despite an abundance of milk-furnishing beasts (they rear cows, buffalo, mares, donkeys, camels, sheep and goats) and despite a long and constant intercourse with neighboring milk-consuming peoples whose habits and mode of life were well known to them; yet they never acquired the habit of milk-drinking. Now what does this fact mean? In the first place it means that our consumption of milk can not be looked upon as a self-evident and spontaneous phenomenon for which it is usually taken, but that it is merely a matter of educated force of habit historically evolved. Objectively it is not natural at all. As "natural" as it appears to us in consequence of time-honored tradition and custom, so just as unnatural, abnormal and barbarous does it impress the Chinese and other nations of eastern Asia. Above all, however, these plain ethnological observations and considerations may lead us to distinguish two ancient culture periods in the early history of Asia which lie beyond all recorded history and archeological monuments. In the first period, which denotes the primary stage in the domestication of cattle, the milking faculty of the cow was unknown to man. The ox was exclusively the sacred animal trained in the service of agriculture solely for drawing the plough, and simultaneously he was the highest sacrifice to the gods of heaven. The invention of the plough and the wheeled cart, as well as the cultivation of cereals, are events closely affiliated with the domestication of cattle. This is the very point which the cultures of eastern Asia have in common with western Asia and Europe. In the second period, western Asia advanced to the stage of dairy economy; this was a slow and complex movement operative on the one hand in the producer, the animal, in which the productive power was gradually trained as the result of a domestication extending over millenniums; on the other hand, in the consumer, man, who just as gradually acquired the habit of taking to milk. This new development remained confined to the West, but it did not affect eastern Asia, and must therefore have taken place at a time when the East was definitely settled in its culture pattern and was no longer ready to absorb extraneous ideas. It bespeaks a lengthy prehistoric cultural development in the East independent of the West. I do not continue this discussion, as I merely wish to cite this case as an illustration of how ethnological methods may carry us into the remotest past and help us to discover and unravel ideas of which no record has been preserved.

The following case is still more instructive, as it will bear out some unexpected results in regard to the domestication of the cock and the pig. The first striking fact in their distribution is the parallel occurrence or non-occurrence of the two. Both pig and chicken are sedentary animals and consequently make their domicile only in sedentary, never in migratory communities. I say advisedly sedentary, not agricultural, because neither pig nor chicken bears any relation to the stage of agriculture and were introduced into the great agricultural civilizations of continental Asia from the more primitive, marginal or peripheral culture-sphere of southeastern Asia. In Tibet with its division into two social groups, an agricultural one in the fertile valleys and a migratory-pastoral one on the high plateaus, pig and chicken are found only among the farmers, but never among the nomads who raise cattle, horses and sheep. Throughout eastern Asia cock and hog are met with as parallel factors for reasons which will become clear after awhile. The sole exception is presented by ancient Japan which had only the cock, not the pig. In Formosa both cock and pig were found by the Chinese at the time of the discovery of the island in A. D. 605. In Polynesia the two occur everywhere, but the easternmost isle, Easter Island, reflects the same situation as Japan; it had chickens, but no pigs, and chickens were the only domestic animals encountered there. New Zealand had neither the pig nor the chicken. Such factors of geographical distribution are the result of historical events, and each case of this kind merits a special investigation.

Coming back to my previous proposition, I now wish to offer an explanation of the motives and circumstances which prompted the original phase of the domestication of these animals, and I shall explain briefly how I arrived at my idea.

A fundamental of culture in eastern Asia is divination. In this respect we have four distinct culture provinces which despite their difference of method share one important point inasmuch as divination is based on the bones of certain animals. Among several ancient and now extinct tribes inhabiting Korea and Manchuria there was a system of divination from the hoofs of cattle and horses and the bones of oxen. In central Asia divination was practiced from the shoulder blade of a sheep which was scorched over a fire, and from the cracks thus arising in the bone the future was predicted. In ancient China the carapace of a tortoise was utilized in a similar manner. The tortoise was regarded as a sacred animal imbued with a knowledge of the future. In 1899 a deposit of several thousand fragments of bones, chiefly tortoise shell, was discovered at Chang-te fu, Honan. These bones are engraved with inscriptions of a very archaic style, representing the earliest form of Chinese script we now possess, and were used for purposes of divination. The oracles and in some cases the answers were carved into the bones. We meet, *e.g.*, inscriptions such as these: "We consulted the oracle to ascertain whether the harvest will be abundant," or "The oracle was consulted, as we wish to know whether God will order a sufficient rainfall so that we may obtain an adequate food-supply," or "If we go a-hunting to-morrow, shall we capture any game?" Divination has always dominated the whole life of the Chinese from the cradle to the coffin, and no business was transacted, no marriage concluded, no burial undertaken, without consulting a fortune-teller. These ancient augurs formed a special profession, in their social position comparable to the lawyer of our society. In the same manner as the modern financier and captain of industry consults his lawyer on all important questions, so the Chinese

did not make a step in the most trivial matters without asking a diviner's advice.

South of the Yangtse and widely diffused all over southeastern Asia we find from ancient times a complex system of divination based on the femora or thigh bones of a cock. Formerly it had a much wider geographical distribution than at present, and was found among the Yüe, a non-Chinese tribe which occupied what is at present the southern portion of Chekiang and the province of Fu-kien, and among the widely extended Miao group in southern China. We have numerous Chinese records of this form of divination ranging from 110 B. C. down to recent times. At present this system of chicken-bone divination is still flourishing among the Lolo, the Karen tribes of Upper Burma, the Ahom and other tribes of the Tai or Shan family, and the Palaung and other tribes of the Mon-Khmer stock. Among all these peoples the cock is a divine or sacred bird, a supernatural creature, a messenger of the gods endowed with the gift of prophecy, with a knowledge of the future and of good and evil. He plays a fundamental rôle in mythology, in tribal migration stories, in prayers and rituals. Among all these people chickens are not primarily kept for utilitarian purposes, and the eggs are hardly, if ever, consumed. The most primitive conditions still prevail there in regard to fowl-rearing, and it is a curious and corroborating coincidence that the same area, Upper Burma, had previously been claimed by naturalists and orientalists alike as the primeval center for the domestication of the cock. Thus it seems to me there are good reasons for concluding that it was the practice of cock divination which was instrumental or at least the principal agency in bringing about the domestication of the bird. The Palaung still capture the wild jungle fowl and cross it with the domestic breed. Eggs of jungle fowl are often brought from the jungle and set under the village hen. The pullets when large enough to look after themselves are sometimes carried to the jungle and there set at liberty. These people are perfectly aware of the relationship of the wild species to the domesticated variety, and the interbreeding of the two continues under their care. They keep cocks essentially as time-keepers and as sacred birds in divination. According to their traditions it was the captive jungle-cock who was first employed for this purpose. Chinese accounts give us the same information with reference to the Miao tribes.

There is a peculiar reason why the Palaung constantly take recourse to the jungle in order to replenish their domestic stock. The thigh bones of fowl have fine perforations, the foramina of the blood-vessels, and these play a prominent part in the procedure of divination. Fine needle-like bamboo splinters are inserted into the foramina and project at various angles from the sides of the bones; according to their position (whether slanting, straight, or upright) good or ill omens are decided. There are books illustrated with over one hundred diagrams of chicken bones with the splinters inserted and accompanied by an oracle in old Shan. In the wild jungle fowl and in domestic fowl bred from jungle stock there is a much greater variation in the position and number of the foramina than in the pure domestic stock. For this reason the bones of the jungle cock are deemed preferable for divination to those of the purely domestic breed. This whole process goes to show that the Palaung are actuated by no other motive than the desire to have the service of the bird's divinatory qualities and that any utilitarian viewpoint is alien to their thought. Unconsciously and involuntarily they have contributed to the improvement and eugenics of their

domestic stock by rejuvenating it with the blood of the jungle fowl, but the sole motive was and is to obtain a bird of a superior degree as the messenger of divine will.

It is a curious coincidence that among the majority of the tribes under consideration, the pig is likewise enlisted for purposes of divination. Among the Karen, the pig is an important sacrificial animal, and its gall-bladder is examined for favorable omens. In their elaborate divination rituals cock and pig function simultaneously. A peculiar condition prevails among the Khasi who draw auguries by examining the lungs, liver, spleen and gall-bladder of a pig; if the liver is spotless and healthy, *e.g.*, the augury is good; if the reverse, it is bad. On the other hand, the Khasi also revere the cock, regarding him as a mediator between the deity and man, yet in opposition to all other tribes of the area they do not use the femora of the cock, but its entrails. Here evidently the basic ideas of the pig complex were grafted upon the ideas of the cock complex, and this example illustrates well that the two complexes are closely interrelated and cultural parallels, and that correlations and adjustments have taken place between the two. The same condition as among the Khasi prevails in Borneo, and traces and survivals of this whole complex go over the entire Malayan, Polynesian and Melanesian area.

Another interesting point is that those primitive tribes to whom cock and pig are essentially sacred animals of religious significance have never developed cock-fights and pig-fights—quite naturally, for such cruel sports are reserved for the so-called higher civilizations. Again, the coincidence is striking that wherever in southeastern Asia we meet cock-fights there are also pig-fights; the two, *e.g.*, occur together in ancient Camboja and ancient Java. Much has been written on cock-fights, but no one seems to have seen what it is all about. This institution has also grown out of a form of divination, save that it is a sophisticated and materialized offshoot of it. In the beginning it was not individuals who set their roosters to fight, but villages and communities entered into a contest against each other to decide the question of superiority by relying on divine judgment that would manifest itself in the prowess of their divine roosters.

I hope that this brief outline is sufficient to show that through intensive ethnological study the history of our domesticated animals can be disentangled and that we may hope in course of time to be able to reconstruct culture sequences and periods in well-defined areas for a number of domestications. Like numerous other culture traits, domestications have been evolved progressively on a line from the irrational to the rational, or to express it more guardedly in terms of relativity, from what we are inclined to regard as irrational to what we are wont to regard as rational. For the Palaung who abstains from eggs, but trusts in the efficacy of the chicken-bone oracle is just as rational and honest and sincere in his way as we are in maintaining chicken-farms and eating cold-storage eggs.

AQUICULTURE AND THE FUTURE OF THE WATERS

By Professor R. E. COKER

UNIVERSITY OF NORTH CAROLINA

No problem of civilized man seems likely to be more enduring than that of enlarging the means of subsistence to keep pace with the increase of his numbers and the growth of his requirements. The chemists and the physicists may some time show us how to manufacture proteins, carbohydrates, vitamins and other necessities from the atmosphere and a little dust. As yet, however, they have not done so. At any rate, sustenance and raiment are now derived from animals and plants growing in or on the cosmetic covering of the face of Mother Earth. The problem, as we seem to have it, then, is to make the best possible use of the available areas of that covering.

We are told that the surface of the earth is nearly three fourths water and about one fourth land. The smaller area that is land is subject to cultivation extensively, and its yield per unit area has been steadily increased, first by the physical labor of man, and, second, through the progressive application of the results of experience and a growing fund of knowledge. Both factors, the physical and the mental, have undoubtedly been applied to the task from the very beginnings of agriculture, but the latter factor, intelligent effort, let us say, has been subjected, especially in very recent times, to a remarkably effective stimulus through the development of modern science and the translation of its fruits and its methods into a system of guidance and control for practical agriculture. We have now added to a practice of agriculture a young but vigorous and growing science of agriculture. This science, or group of sciences, may be immature, but it has safely passed the age of adolescence and no one questions its ability to endure and to perform a service of constantly growing significance to human welfare.

The far greater areas that are water, like the lesser areas that are land, had first to go through a period of exploitation, but, unlike the latter, they have scarcely passed beyond that crude stage. There has been some application of manual labor and intelligence to increase of production through governmental agencies, and, in some instances, through personal enterprise (oyster farming is an apt example); but it can certainly be said that there exists now no practice of water-tillage comparable in any degree to that of recent soil-tillage, and, correspondingly, there is no worthy science of aquiculture. We may not love the word "aquiculture," but etymology, logic and usage offer no substitute.

It is not out of place to inquire as to the causes of the remarkable lag of aquiculture, as compared with agriculture, in practice and in science. In the first place, let it be admitted at once that the comparison of three to one in favor of water as composing the surface of the earth is to an extent misleading when applied to the question of the utilization of the areas. We have no reason to assume (and none to deny) that science can ever make the greater part of the broad seas actually productive beyond its primitive condition. The applications of practical aquiculture, so far as we can now see, are to shore waters, enclosed waters and

rivers. The open sea, however, does demand the attention of science for its problems of conservation and of intelligent control of exploitation, if for no other reason. But our question remains: What are the causes for the lack of development of aquiculture in those regions that are subject to control?

The principal cause I believe is this: The obvious obscurity (if such a paradox be allowable) of the conditions and results of experimentation when applied with reference to the productivity of water areas. The land farmer plants or fertilizes and day by day observes with satisfaction or disappointment the results of his effort and thought. The water farmer may plant and fertilize, but he sees nothing—nothing that he can intelligently interpret. Rule-of-thumb methods develop more quickly and successfully in agriculture than in aquiculture. It may be said that the conditions of the soil are also obscure and complex and that the land farmer does not actually see all the results of his experiments and that he can not fully and correctly interpret what he does observe. True enough: as we know, he soon reaches the limits of purely empirical experiment when he must pass the problem to the agencies and the implements of scientific research. The difference as regards aquiculture is that such a limit is reached almost at the beginning and before the infant industry can have attained a clearly articulate stage. The application of inductive science naturally develops most rapidly in a field alive with empirical science—a field, let us say, which has regularly yielded crops of recognized value, has engaged a considerable number of more or less thoughtful laborers, has demonstrated its responsiveness to intelligent effort and has conspicuously sprouted its problems. As an illustration of this fact, may we recall that one of the most vocal demands for the aid of science to aquiculture comes from the relatively highly developed industry of oyster culture? The oyster farmers have seen sufficient results accrue from their own practical experiments to conceive of the possibility of aid from those possessing greater technical knowledge and the command of scientific method.

A second cause of the relative lack of development of aquiculture as compared with agriculture is the difference in ownership or control of the areas involved. Private ownership of land not only stimulates personal effort for increase of productivity but also prompts the demand for outside aid, and even science bearing gifts is not scorned. To illustrate again, no demand for the service of science comes from the exploiters of public areas of oyster production, but only from those who have a vested interest in particular sections of the bottoms of coastal waters. I believe, however, that the slight development of private ownership of water areas is to a large extent a secondary cause and a result of the primary cause first mentioned. The lack of conception of possible gain proportionate to effort inhibited the assumption of control at times when private ownership of the surface of the earth was first coming into being.

With such causes at work in the past and the present, why will they not continue indefinitely in the future? The answer is—the development of science. Science will call forth the industry which did not rise up to cry for it. The development of the sciences necessary to promote aquiculture lies largely in the hands of those who are permitted to look into the future rather than to minister solely to the immediate demands of industrialists, in short, with the men and the agencies of science and with governments to such an extent as a more enlightened public policy may take cognizance of the need of attacking fundamental problems for service of the future.

To put in summary form the outline

comparison of the progress of agriculture and aquiculture and the probable future of the application of science to these industries:

With regard to agriculture, there was first an era of exploitation of public areas, then communal cultivation stimulated by the favorable results obviously obtained from the application of labor and thought; later the development of private ownership in most countries and application of empirical science, crude at first but progressive. Later agriculture becomes a private enterprise of the first rank among human occupations—the era of application of empirical science. There follows the birth of a science of agriculture in supplement to the efforts of private enterprise—such a science in this country dating practically, I presume, from the birth of the United States Department of Agriculture in 1862. There has ensued a further development of the science of agriculture stimulated by the definite consciousness of need on the part of agriculturists. In the future we may anticipate enduring vigor of agricultural science supported by a clientele eager for its aid and assured of its practical utility.

As regards aquiculture, we started with an era of exploitation of public areas and have progressed very little beyond that point. There was a limited development of private ownership and control in ancient times, as witness the fish cultural practices of the Romans and others of the older peoples. Aquiculture became a sporadic enterprise of secondary importance, with some development of empirical methods to increase production, chiefly in the growing of oysters and the cultivation of carp, tench, goldfish and trout. There has been a very slight development of a science of aquiculture beginning in this country, we might say, with the establishment of the United States Fish Commission in 1871. Its further development has been retarded by the lack of a responsive clientele of aquiculturists and perhaps by the actual distrust of many of the exploiters of public waters. For the future we may anticipate a more vigorous growth of aquicultural science, promoted primarily by a public consciousness of its importance to mankind.

This outline history points to two conclusions. The application of science to the utilization of water areas will arise not so much from the needs and demands of practical aquiculturists who seek to preserve and enlarge an accustomed livelihood as from the foresight and resolve of those whose vision encompasses its possibilities. Any extensive development of aquicultural practices will be the fruit of aquicultural science rather than the reverse.

If these conclusions are correct, we have anticipated one answer to a question which must arise some time in the minds of every one: Why concern ourselves with the need for utilization of water areas? Why not leave such problems to the sure working of economic laws which will apply the solution whenever the stringency becomes sufficiently tense? Now, the writer will frankly confess that, after a good many years of more or less vain argument in the cause of aquiculture, he found himself settling into the attitude represented by that question. We ought to make better use of water areas, he thought, but there is no need arguing about it. Leave it to time. When the pressure is sufficient, when the population can no longer find full sustenance from the land, the waters will come inevitably into their own. Out of this lethargic and fatalistic attitude he was shaken by three considerations. One was such a mental review of the history of the case as has been given above, from which it appeared that, however satisfactory economic laws might generally be, they would not work to a proper conclusion in this case. The second was a loss of faith, which is perhaps becoming somewhat general, in the certainty of

operation of some so-called economic laws. If the pressure of need inevitably causes productiveness, then the most over-populated countries should have the most efficient systems of agriculture, and we should look to India and China for the highest development of agricultural science, and to all tropical countries with their wealth of disease carriers for the chief advances in medical science. Yet it is not so. Something else than economic need accounts for the growth of science. Something other than necessity mothers invention. If intelligence and enlightenment, or whatever it is that gives a people vision and resolve, that lifts them above the bondage of daily digging for physical sustenance, if such are the forces that fertilize the other sciences that promote human welfare, is it not upon these also that we must rely for the developments that we now have in mind? It is in no way expressive of doubt nor savoring of pessimism to assert that the future of aquicultural science is contingent, not upon the near approach of starvation, but rather upon the maturity of a conception among enlightened people that it is useful and worthy of the effort to produce it.

Now it was said that there were three factors which disturbed a formerly lethargic attitude. Perhaps chronologically the third, which has not yet been mentioned, worked first upon our convictions. It is this. We may leave to time the solution of our problem of the proper use of waters; but, while we serenely wait, the waters pass from us. The seas may be the embodiment of endurance, but the primarily productive areas of shore and tributary waters can be changed and are being changed in ways that diminish their productiveness. This is not the place for argument or for detailed data; but it is undeniable that the general trend is downward as regards practically all animate resources of the coastal regions and of the rivers and lakes of the interior. The writer has recently had occasion to look into the trend of the fisheries of the greatest of our river systems, and any one who does so will be astonished at the steadiness of the decline in the productiveness of the waters of the Mississippi basin during the past thirty years. We may speculate as to the causes, but the results are not obscure. Let us cite a particular incident that may be suggestive. Not many years ago a great dam was constructed across the Mississippi River. It may have checked the passage of a few fishes, but it provided broad flood areas for the production of food and for nurseries of young fish. In a few years there appeared a striking upward spurt of the local yields of some commercial fishes; very soon, however, it was held necessary to build levees and to put under land cultivation the best part of the breeding grounds of the fish, and a few more years saw the yields of the fishes for several of these species fall far down again. Here is a series of clearly established facts in chronological order, whatever may be the relations of cause and effect.

We may wonder what are the causes of the steadily diminishing importance of the fisheries of our chief river system. A decline noted during a period of a few years may not be significant, but, when the downward movement ensues without break during a period of thirty years, we have a trend that can not be viewed with complacency. We know there are causes at work, and we wonder if the causes and the results are inevitable.

We are confronted with two sets of problems. First, there are the special problems presented by each and every species of useful animal or plant of the waters. What are the conditions necessary for its perpetuation in maximum abundance? Problems of the cultivation or conservation of aquatic resources. Second, there are the problems of the preservation of the waters themselves. What are the conditions and practices that will best maintain the rivers, lakes and coastal waters in condition of maximum productiveness? And this last

problem, simple as it may be in the stating, leads into an amazing complex of interrelations. The improvement of streams for navigation, the building of dams and treatment of the pools formed by them, the maintenance of shores of streams and lakes, the making of reservoirs for flood control, the formation of innumerable ponds for domestic uses, fish ponds and stock-watering ponds, the drainage of overflowed lands along great rivers and bordering the coasts, the disposal of sewage and industrial wastes, the ditching and tiling of agricultural land, deforestation and reforestation—these and other expressions of man's activity all have their bearings upon the productiveness of streams and lakes.

And the reciprocal relations of a proper policy of water conservation—its bearing upon flood control, navigation, forestry, agriculture and climate—these are of no less significance. There may be conflict of interests and a wise policy can be followed only by the sacrifice of one or the other; but there is reason to believe that the conflicts are not so great as might be supposed. The past attitude, according to which almost every case involving waters is presumed to be decided without consideration of aquatic resources, is clearly wrong. There is evidence to indicate that the sacrifice of water conservation entails in the long run a sacrifice of the resources of the land. I seriously doubt if there is any substantial conflict between the causes of aquiculture, flood control, navigation, forestry and agriculture. In any event, the ultimate policy with reference to land and waters must be based upon a broad view of the whole problem in all its bearings and with the fullest possible information regarding the conditions and relations of each sphere of interest.

In this very hasty review of a subject large in its significance and complex in its relations, we have sought to develop three chief points. Let us recall them. First, there is strong need for more extensive and intensive application of science to the problems of the conditions of life in waters, both for the possibilities of improving productivity and for the regulation of the use and exploitation of the waters under conditions of natural productivity. Second, the utilization of waters and the relevant studies have lagged far behind the utilization of land and the application of science to its problems; but the lag has been due not to lack of need or potentiality so much as to the difference between the two cases as regards the conditions of practical experimentation. The land yields to rule-of-thumb methods more generously than the water, which reserves the secrets of its productivity from the rough experimenter. From this follows our third and concluding thesis. The natural order of development of practice and science in the field of aquiculture will be the reverse of that which has prevailed in respect to agriculture. Instead of finding a well-developed and vigorous industry to call science to its aid, we must in this case start mainly from the scientific end and let science to a great extent generate the industry which will require its guidance.

We do not at all mean to imply that this is a unique instance of the necessity for a creative function on the part of science. It is, however, a case where progress is more purely dependent upon that function than in other cases of the basic industries. Modern science is young, but growing in influence, power and responsibility. More and more in the future will it serve to create industrial practices and public policies. We believe we are citing a particular instance where creative effort on some part is called for, and we have no doubt that in the end it will be the stimulus and the guidance of science which shall lead us to make the fullest response to the primeval command: "Let the waters bring forth abundantly the moving creature that hath life."

VOCAL THERMOMETERS

By BERT E. HOLMES

In common with nearly everyone brought up in the country, I learned, when quite young, that crickets do not chirp when the temperature approaches the freezing point. But not until the fall of 1923, when my attention was directed to the matter by an office associate,[1] did I suspect that a definite and measurable relationship exists between the rate at which crickets chirp and the prevailing temperature. Having sensed the possibility of the existence of this relationship, I immediately began making observations and have since made them whenever possible. During the falls of the four years 1923–'26, I made about one hundred and thirty-five. These observations prove that a remarkably close relationship does exist between the rate of chirping and the prevailing temperature. Also, they yield a formula which explains the relationship.

This formula is expressed below in two ways: first, as a simple and practical rule which one can use when experimenting with this interesting phenomenon, without the aid of pencil and paper; and second, as an expression developed by means of refined mathematical methods. The latter, of course, also can be used for the purpose of experimenting, but its use demands more time and pains than are required when the simpler rule is employed.

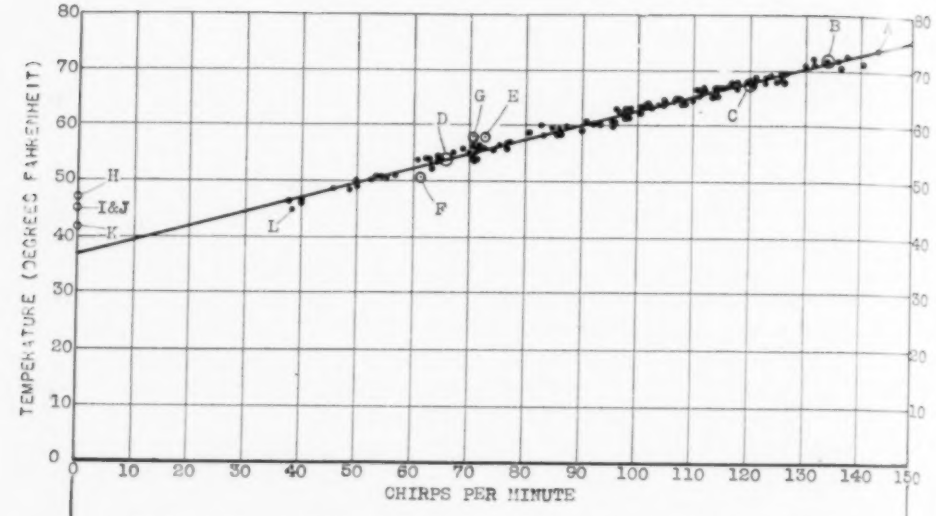
The simpler rule is: "The prevailing temperature (degrees Fahrenheit) equals the number of chirps made in 15 seconds, plus 37." One can try out this rule merely by counting the number of chirps made in a quarter of a minute, mentally adding 37 to the count, and then comparing the result with the temperature as shown by a thermometer. On the average, the difference between the calculated and actual temperatures ought not to be greater than one degree.

The formula as derived mathematically, by the method of least squares, is: "The prevailing temperature equals 258 one-thousandths of the number of chirps made in one minute, plus 36.9." By using this formula and taking greater care when making observations, one will get more accurate results than can be obtained by means of the other rule. It is well to count the chirps for at least two minutes, and then to calculate the average per minute, carrying the result to one decimal place if necessary. The thermometer reading should be made as accurately as possible, preferably to fractions of a degree.

The upper section of the accompanying diagram shows the formula expressed as a straight line. This line starts at the left edge at about temperature 37° and rises as it proceeds toward the right edge of the diagram. It will be seen that this line rises about 1° for every four chirps per minute that it moves to the right—just as the cricket makes about four chirps more per minute for each degree which the temperature rises.

Each dot or circle which appears on the diagram represents an observation. For example, the dot "A," which appears near the upper right corner of the diagram, shows that when a particular observation was made, the temperature was 74° and the cricket was chirping 143 times per minute. And so on. See how close to the formula line nearly all of the dots and circles are. They hover around it during its entire length. This

[1] Mr. Edward J. Hunt, New Haven, Conn.



The line around which the dots cluster represents the relationship which exists between the rate at which crickets chirp and the temperature. Each dot or circle represents an observation, being located at the intersection of the chirps-per-minute and the temperature lines. For example, the dot "A", which appears near the upper right corner of the diagram, shows that when a particular observation was made, the temperature was 74° and the cricket was chirping 143 times per minute. Note how the chirps per minute increase as the temperature rises.

B Observed at New Milford)
C. " " " ")
D " " Kent)

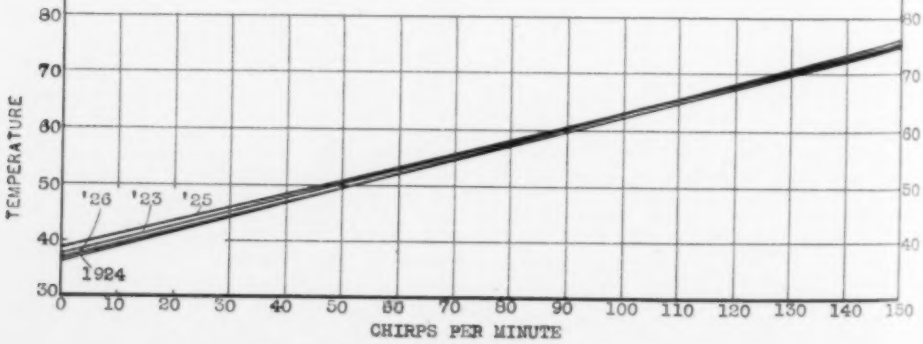
These three observations, which are practically on the formula line, were made fifty miles inland from New Haven, where the others were made.

E. Observed Oct. 7, 1924)
F. " Sep.30, 1926)
G. " Oct. 6, 1926)

These three, the only ones whose dots fall more than 2° from the formula line, were all taken near the end of the season.

H. 47 degrees; no chirps)
I. 45 " ; " ")
J. 45 " ; " ")
K. 48 " ; " ")

The chirping stops at about 45°, only one observation(L)having been made at this temperature and none having been made below it. Between 45° and 47° three observations were made.



Here are shown the formula lines for the individual years 1923, 1924, 1925 and 1926. Note how little they vary.

association illustrates the remarkably close relationship which exists between the temperature and the rate of chirping—a relationship which holds over a range of about 30° in temperature, or from the summer temperature of 75° or so which prevails when the first cricket peeps, down to that—about 45°—which signals the arrival of fall and puts an end to the chirping.

How close to the formula line are the dots? Well, there are 115 of them, of which:

52, or 45%, are within ½ of 1 degree of the formula line
34, or 30%, lie between ½ degree and 1 degree of this line
20, or 17%, lie between 1 degree and 1½ degrees
6, or 5%, lie between 1½ degrees and 2 degrees
3, or 3%, are more than 2 degrees distant from the line.

Another way of saying this is:

52, or 45%, of all the dots are within ½ of 1 degree of the formula line
86, or 75%, are within 1 degree
106, or 92%, are within 1½ degrees
112, or 97%, are within 2 degrees
115, or 100%, are within 2.97 (greatest deviation = 2.96).

Although 135 observations were made, only 115 were considered in connection with development of the formula. Of the 20 whose results were not used, the greater number were made under conditions affecting their reliability—crickets were at a considerable distance and therefore hard to hear; or were chirping intermittently, as they do in the relatively low temperatures which obtain near the ends of seasons. In the remaining cases, although readings of temperature were taken, there were no crickets chirping. The value of these latter observations lies in the fact that they tend to show at what temperature the chirping ceases. A few of the temperature readings which were recorded when no chirps were being sounded are shown at the left edge of the upper section of the diagram. These will be referred to again.

For a time, I suspected that significant deviations from the formula line might be due to excessive moisture in the air, this causing the crickets either to speed up or to slow down. This is not so. Crickets will continue to chirp during a drizzling rainstorm. In fact, they are stopped by only a reasonably heavy shower. When they are forced to stop because of rain, they very frequently quit for the evening, even though the latter part of the evening be clear—but as long as they chirp at all, they chirp at the standard rate for the prevailing temperature.

Some of the deviations from the regular rates of chirping doubtless are due to differences between individual crickets; but the principal cause of fluctuations in rates is, I believe, differences between the conditions under which the chirps are made. Upon one occasion, the cricket under consideration may be beneath a stone or pavement which has retained heat obtained from the sun; while, again, he may be out in the open air in the pathway of a breeze.

The third footnote refers to the temperature at which the chirping ceases. This point is in the neighborhood of 45°, no consistent chirping having been observed at temperatures lower than this. As will be noted by reference to the footnote, twice, when temperature readings of 45° were taken, no chirps were being made. In numerous instances, when temperature readings of from 30° to 40° were taken, no chirps were being sounded.

The lower section of the diagram carries four formula lines, one for each of the years 1923 to 1926 inclusive. These formulas follow:

For 1923, the temperature equals .254 times the chirps per minute, plus 37.7. This is based upon 21 observations.

For 1924, the temperature equals .265 times the chirps per minute, plus 36.3. This is based upon 23 observations.

For 1925, the temperature equals .243 times the chirps per minute, plus 38.8. This is based upon 37 observations.

For 1926, the temperature equals .252 times the chirps per minute, plus 37.0. This is based upon 34 observations.

In a number of instances, the making of a satisfactory observation was a time-consuming process which required up to nearly a half hour's painstaking attention. Regularly, interference was caused by radios, by the rumbling of trolleys and by autos whizzing along nearby streets. At times, the sounds made by insects other than crickets tended to drown out the one note desired.

It is strange that although during the fall I invariably was able to find crickets by the dozen during the day, it was only upon most infrequent occasions that I could hear more than one or two chirping in the evening. Upon one occasion, when there were two, chirping at very slightly different rates, the resulting overlapping so hindered me in my attempts to obtain a correct count that I found it necessary to disturb one of the vociferous chirpers slightly in order to have him remain silent while I completed the observation.

During the first week of June, 1925, we had some almost unbearably hot weather. The newspapers regularly kept us informed as to how many decades had passed since we had been visited by an equally hot June 2nd, 3rd, etc. Toward the end of the week, or on June 5th, I heard a cricket. In so far as I know, I never before heard one in June. Had it been prematurely hastened into being by the unseasonable weather, I wondered; and what would he do? Well, for two days he faintly and intermittently proclaimed that he was alive, and then he stopped. I heard not another chirp for about six weeks. Oddly enough, one lone faint peeper made himself heard late in May during 1926. For just one evening he chirped in a hit-or-miss sort of way. Then—not another chirp until early August.

I have noted two kinds of chirps. Those usually made are the well-known shrill ones, which are regularly sounded, in many cases for the greater part of an evening. The others are hardly more than little squeaks, and are often made for very short intervals of time, and in unison with a series of the regular sounds. It is as though a young, inexperienced cricket were trying to keep pace with an older and practiced one. If this is the case, the attempts are successful, as the two sets of sounds synchronize perfectly, as a rule, as long as the little cheeps are made; but an "attempt" often consists of but a half dozen, and seldom of more than twenty, squeaks.

As the season draws to a close, and the chirps are made more slowly, it becomes clear that what earlier in the season seemed to be one continuous sound is in reality three or four very short sounds linked closely together.

Here is a wonderfully interesting phenomenon! These little creatures, the crickets, are with us for nearly two months during the late summer and early fall of each year; meanwhile chirping practically every evening, in places innumerable. And the frequency with which all of the resulting chirps are made is controlled by something outside of the crickets themselves! "Why?" one asks. But the answer to this question, like the answers to the other interesting questions regarding the subject which crowd into the mind, must await the results of further investigation and study.

AMERICAN WILD HORSES[1]

By Dr. JAMES W. GIDLEY

U. S. NATIONAL MUSEUM

THE domestic horse may be found to-day in almost all parts of the civilized world. From a time even before the dawn of recorded human history he has been a factor in the daily life of mankind and has occupied a vitally important place in the development of modern civilization. This long and useful association has endeared him to man, making him for many the favorite among our domestic animals. And rightly so, for without him the high standard of development which to-day marks human progress towards higher civilization would have been impossible. Before the days of the steam engine and the railways the horse was man's chief means of getting from place to place and was the chief source of power for land traffic of all kinds; he was indispensable to the early pioneers in seeking out and developing new territories for the habitations of man. And even since the advent of the railways, within the memory of most of us grown-ups, horses and horse-drawn vehicles have been most important auxiliaries to the railways for land transportation, and not so long ago furnished about our only means for joy-riding on Sundays and holidays. The usefulness of the horse in war has been praised in song and story from time immemorial, and for many hundreds of years he has been the chief reliance of the farmer in tilling the soil and harvesting his crops.

But the invention and development of the automobile and motor truck is changing all this; and to-day the scope of usefulness of the horse is being increasingly narrowed. He has almost disappeared from the streets of our cities and the main highways of the country, and is now confined principally to the farm, the ranch and undeveloped outlying districts which have not been reached by the railroads or graded highways.

The horse is also still much employed in the equipment and movements of modern armies, but not to the same extent as formerly. In the field of sport, only, the horse seems to be holding his own to-day. Here he is still king; and it is here perhaps he has reached the acme of physical development, as seen in the various strains of blooded "racers" and "hunters." In this connection it may be noted that these aristocrats of the turf, as well as the various breeds of great draft horses, the Shetland pony and all other distinctive varieties of domestic horses, are the products of selective breeding intelligently directed by man over a very long period of time; and also that they all were originally derived from only a few kinds of wild horses which once were native of certain localities of the Old World, including northern Africa, Arabia and Mongolia.

Thus the word horse became a household word many centuries ago and such it has remained, but to-day it is generally applied to the domestic breeds only. However, the naturalist's conception of the term is a vastly wider one and includes not only the living asses and zebras of the Old World, which are very near relatives of the domestic horse, but a very large number of kinds which in-

[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark and given from Station WRC, Washington.

RESTORATION OF EQUUS SCOTTI GIDLEY,
ONE OF THE AMERICAN HORSES OF THE PLEISTOCENE OR GLACIAL PERIOD. THE SMALL FIGURE IS EOHIPPUS INSERTED TO SHOW THE RELATIVE SIZE.

habited the earth long ages before the earliest human records were written.

The geologic records show that these earlier horses were far more numerous and diversified in kind than the horses of to-day, and going backward in time they are seen to be less and less like their living successors, although they all possess certain characters of body structure that stamp them as belonging to the same natural group of animals.

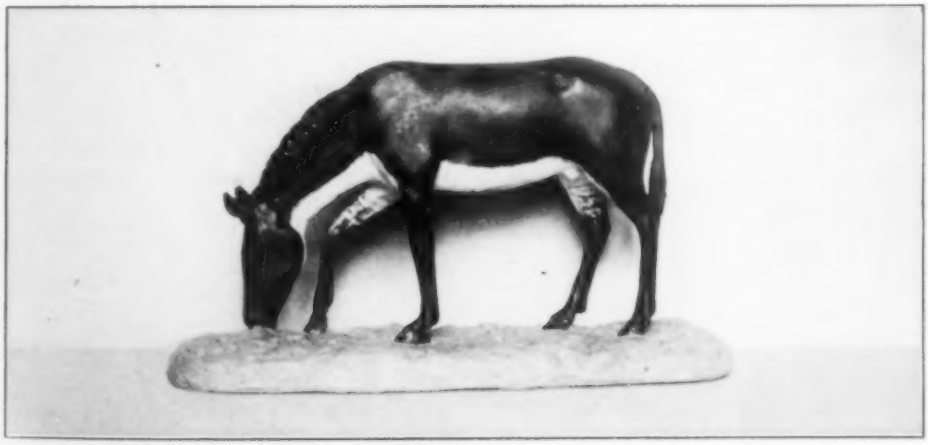
These older or prehistoric members of the horse family may quite appropriately be called the "ancient wild horses" and it is about that part of their history which belongs to America I wish especially to speak.

Nature has been most generous in storing and preserving, in the various rocks and earth-formations of past ages, the fossil remains of these early horses. In consequence their history may be read with an unusual degree of accuracy. Of most of the important kinds many skulls and skeletons are known; so that our reconstructions of body structure, whenever attempted, and studies of relationships are based on sufficiently adequate and abundant observed facts to make them reliable; and they in no true sense can be called the products of guesswork, as sometimes has been falsely remarked.

At the time of the discovery of America and its exploration by the early Spaniards, this continent is thought to have had no native horses. Be that as it may, in the prehistoric period just preceding our own time, known as the Pleistocene or so-called "Ice Age," true horses of many varieties roamed in great numbers over most of the American

RESTORATION OF NEOHIPPARION WHITNEYI GIDLEY,

ONE OF THE THREE-TOED HORSES OF THE BEGINNING OF THE PLIOCENE, REPRESENTING A STAGE IN WHICH THE LATERAL TOES WERE PRESENT BUT DID NOT REACH THE GROUND.



RESTORATION OF MERYCHIPPUS SEJUNCTUS COPE,

ONE OF THE THREE-TOED HORSES OF THE MIOCENE IN WHICH THE LATERAL TOES REACHED THE GROUND AND IN WHICH THE TEETH WERE OF THE HIGH CROWNED TYPE, THOUGH RELATIVELY NOT MUCH HEIGHTENED.

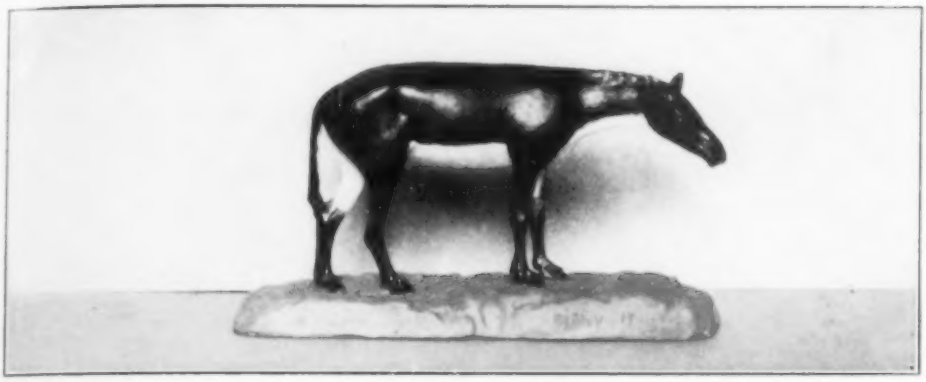
RESTORATION OF HYPOHIPPUS OSBORNI GIDLEY,
ONE OF THE ABERRANT THREE-TOED HORSES IN WHICH THE LATERAL TOES WERE WELL DEVELOPED AND THE TEETH WERE OF THE TYPICAL LOW CROWNED TYPE.

continents, both North and South; and their fossil remains have been found in all parts of the United States, in Mexico, Central and South America, and far north in Alaska even beyond the Arctic Circle. The horses of this period were all modern in type, and in life differed little or not at all in general appearance from the horses of to-day, but each kind possessed certain features which, to the naturalist, marked them as distinct from their living relatives and from each other. Like the living horses they were relatively long-limbed with a single toe and hoof on each foot, and their skulls were long-muzzled with deep jaws to accommodate the long high-crowned teeth so characteristic of the modern horse. In size they ranged from little animals no bigger than the smallest Shetland pony to kinds that excelled the largest draft horse. The period of existence of these horses extended over many thousands of years and as a group they seemed to have been very well fitted to continue on the American continent. Why they did not is an unsolved problem.

But this is by no means all the story of the wild horses in America. These horses of the Pleistocene were preceded by others of a still earlier geologic time. The fossil records of the later portion of the so-called Tertiary period, known as the Miocene and Pliocene epochs, give abundant evidence of earlier groups of horses even more varied in types and numerous in kinds than their successors of the Pleistocene just described.

The duration of this period was relatively very long, being measured by hundreds of thousands or perhaps millions of years, and the records show that horses were abundant from its beginning to its close.

There were no very large horses at this time, and the general average size of all was notably smaller than that of their successors. Like their successors they all resembled modern horses in a general way, but most of them presented somewhat more noticeable differences. Most of them in fact differed in several rather inconspicuous but very important characters. These differences are especially observable in the structure of the



RESTORATION OF [illegible]HIPPUS BAIRDI LEIDY,

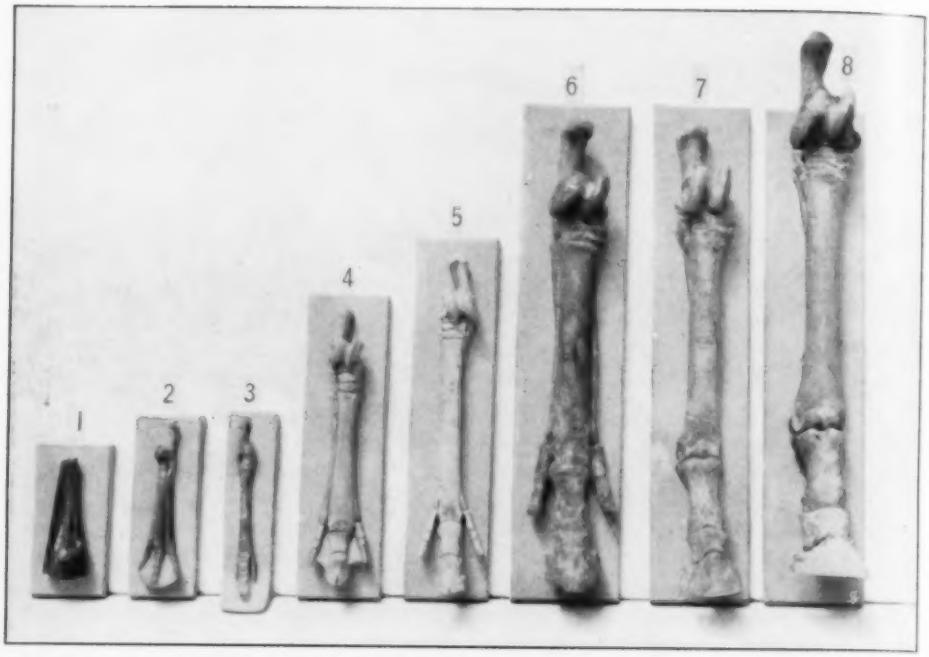
A TYPICAL THREE-TOED HORSE OF THE OLIGOCENE HAVING THE LATERAL TOES REACHING THE GROUND AND THE JAWS SHALLOW WITH THE LOW CROWNED TYPE OF TEETH.

feet and skulls. The limbs and feet of the horses of this period were much like those of modern horses, but in addition to the single, rounded hoof most of them had on each foot a pair of extra toes, one on each side of the main toe. These extra toes varied in size from small ones, resembling the dew-claws of a deer or elk, which did not reach the ground, to larger ones which reached the ground and must have borne some of the weight of the animal in walking. A very few kinds of this period had feet like the modern horses; that is, entirely without the lateral toes, but their remains have been found only in the upper or late section of this great time period. It is a noteworthy fact that most of the horses of the earlier phases of this period have longer and better developed lateral toes than those of the middle and later phases.

All horses with single toes, both modern and extinct, have a pair of long splint-bones on each foot, which lie closely appressed one on each side of the main toe. These do not appear on the surface, as in life they are covered by the skin. The upper ends of each of these bones are greatly expanded and have well-developed articular faces for contact with the small bones of the wrists and ankles. It is important to note that in the three-toed horses this part of the

RESTORATION OF EOHIPPUS INDEX COPE,

THE "DAWN HORSE," WITH FOUR TOES ON THE FORE FEET AND WITH A RELATIVELY SMALL SHORT MUZZLED HEAD.



HIND FEET OF DIFFERENT TYPES OF HORSES AND HORSE-LIKE CREATURES
1. EOHIPPUS (EOCENE). 2. OROHIPPUS (EOCENE; IN THIS CREATURE THE FORE FEET HAD FOUR TOES). 3. MESOHIPPUS (OLIGOCENE). 4. MERYCHIPPUS (MIOCENE). 5. HYPOHIPPUS (MIOCENE). 6. HIPPARION (PLIOCENE). 7. EQUUS (PLEISTOCENE). 8. EQUUS (RECENT).

foot is identical in structure with that of the one-toed kinds of horses, and that they differ in foot structure only in the presence in one and the absence in the other of the terminal three bones of the lateral toes.

In the skull structure of these animals, the principal differences to be noted are that the muzzle portion is usually relatively shorter than in the modern horse and the jaws are not quite so deep, due to a difference in relative height of the crowns of the cheek-teeth. In the Pleistocene and modern horses all the cheek-teeth when fully formed have long nearly straight crowns three to four inches or more in height. These are set deeply in the jaws and move outward as they are worn away by use. It is this type of tooth which gives the great depth to the jaws of modern horses. In most of the horses of the later Tertiary the cheek-teeth are of this type, but the crowns are less heightened and are usually much more curved. Both these factors tend to decrease the depth of the jaws.

A few kinds of horses of this period had teeth of a simpler type, in which the crowns are low and are attached to the jaws by means of roots. These kinds are for the most part found in the earlier phases of the period. It is also true that, of the kinds which have the high-crowned type of teeth, those with least heightened crowns are likewise found in the earlier part of this time period. And this group of the earlier horses represent in a way a transition stage between the strictly low-crowned tooth types, and the horses with the high-crowned types of teeth. For the young, or colts, of these kinds had cheek-teeth of the low-crowned type, which in adult life were replaced by teeth of the high-crowned type.

Referring again to the geologic records we find that in the next older epoch of the Tertiary period, known as the Oligocene, which in itself covered many thousands of years, still other kinds or species of horses inhabited the American continent. These more ancient relatives were smaller on the average than those of the next later period just described. Most of them were about the size of a shepherd dog or a little larger. A few were somewhat smaller. There were many kinds of these little horses and they were widespread in their geographic range, their remains having been found in many places in the west, in Canada and even in Florida. All were three-toed types with the lateral toes reaching the ground, and all had the low-crowned type of teeth and except for their smaller size must have closely resembled those of similar type, already mentioned, belonging to the next later period.

But even these are not the earliest known relatives of the horse. For all through the sedimentary rocks of the earliest epoch of the Tertiary, the epoch known as the Eocene or "dawn time," there are records of an abundance of little creatures much resembling those of the Oligocene, just described, only still more diminutive in size. They also had a main central toe with a well-developed lateral pair on each hind foot, but the fore feet were provided with four toes in place of three. There were slight differences, too, in the skull structure of these Eocene horses. These consist in technical differences of the teeth, important only to the naturalist and in modifications of the muzzle portion of the skull, which was relatively shorter than in the horses of later ages; so that the position of the eyes was about midway between the ears and the tip of the nose instead of being placed back nearer the ears as in later horses.

Thus we come to the oldest member of the four-toed group, which is also the oldest known member of the great group to which all horses belong. He was a little creature no bigger than a fox, and he has been very appropriately called *Eohippus*, a name which means "dawn-horse."

No known members of the horse family have five complete toes, but some of these little four-toed ones have in the foot an extra, small bone of splint-like shape that can only be interpreted as meaning that their ancestors, none of which have yet been found, had the full complement of five toes, the primitive number for all back-boned animals.

IRON CRYSTALS

By Dr. L. W. McKEEHAN

THE BELL TELEPHONE LABORATORIES

THE technical staff of the Bell Telephone Laboratories is always on the lookout for new materials and new methods which give promise either of better efficiency in telephone apparatus or of better insight into the physical behavior of materials already in extensive use. The recent announcements by English, Japanese and German investigators that single crystals of iron possess peculiar magnetic properties were therefore of special interest to the men responsible for improving the magnetic elements of telephonic equipment. One of the most striking of the newly reported facts is that magnetic hysteresis losses in single-crystal iron may be much lower than in "magnetic" iron of the usual commercial sort, which has approximately five million crystals per cubic centimeter. Since hysteresis is so fundamental in any explanation of ferromagnetism and is so embarrassing on its own account, interest in large iron crystals is natural enough. This interest has already resulted in the discovery of a new way of "growing" iron crystals for, at least, experimental purposes.

The crystals here dealt with would not have been recognized as such a few years ago, for it is only since X-ray methods were applied to elucidating the structure of metals that it became clear that the atoms in the grains of the metallurgist are arranged regularly in the geometric ways which give rise in transparent substances to the optically recognizable crystals first studied. Metal crystals very rarely have boundaries which indicate this structure and, naturally, never do when the process of making the metal has required them to be in contact with each other and formed their exposed surfaces in predetermined positions.

The reason why iron crystals must be artificially cultivated is, of course, that they do not grow wild. Some fairly extensive crystals which are mostly iron occur in silicon steel sheet as prepared for magnetic purposes and in a few other cases crystals big enough to work with have been found in the upper parts of huge steel ingots. Such haphazard crystals are not of the right shape for easy magnetic examination and in using them there is always the fear that the act of making them the right shape has played hob with the magnetic properties to be studied.

A straightforward way of tackling the job is to take a piece of iron of preferred size and shape and to form one crystal from the many which actually compose it. There are two ways of doing this, one being old and the other being the new method referred to above. The old way is due originally to Professor Albert Sauveur of Harvard University. The details depend upon the experimenter, but the essentials are: (1) that the iron be annealed so as to give it a nearly uniform grain-size, with grains not too coarse and not too irregular in shape; (2) that the piece be over-strained, not too much nor too little; and (3) that the temperature be raised slowly enough and high enough so that one grain (perhaps not one of those originally present) will grow so large as to occupy the whole of the strained portion. The control of the various steps is not easy and even when

FIG. 1.—APPARATUS FOR CONVERTING IRON WIRE INTO A SINGLE CRYSTAL. THE OPERATOR IS EXAMINING A SINGLE CRYSTAL GROWN IN THE APPARATUS IN FRONT OF HIM. THE WIRE TO BE CRYSTALLIZED IS HELD VERTICALLY IN THE APPARATUS AND THE SOURCE OF HEAT WITH ITS ASSOCIATED APPARATUS IS CARRIED BY A REVOLVING SCREW ALONG THE LENGTH OF THE WIRE.

the greatest care is taken the experimenters report that failures outnumber successes.

The new way was devised by the writer. The essentials are: (1) that the iron be heated much above 900° C; and (2) that it be cooled progressively and not too fast in such a way that at every moment the part cooling through 900° C is a very thin layer in a region of steep temperature gradient. These conditions are met by moving a hot spot steadily along a vertically supported rod or wire. In the latest design of apparatus the heating is provided by an electric current carried by the millimeter wire in which the crystal is to appear. The contacts through which the heating current enters and leaves the piece are rigidly connected and are carried by a lead-

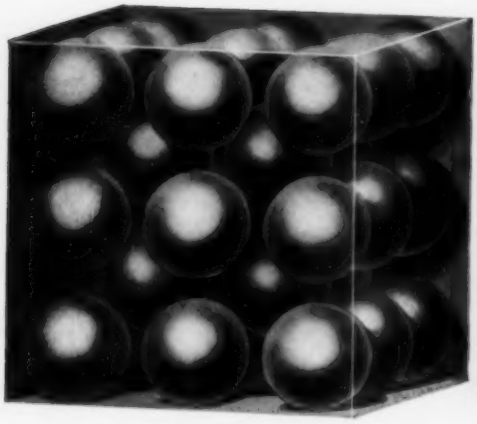


FIG. 2.—THE ARRANGEMENT OF ATOMS IN γ-IRON, THE FORM STABLE ABOVE 900 DEGREES CENTIGRADE. THE FACES OF THE CUBE SHOWN ARE OF THE CRYSTALLOGRAPHIC FORM {100}.

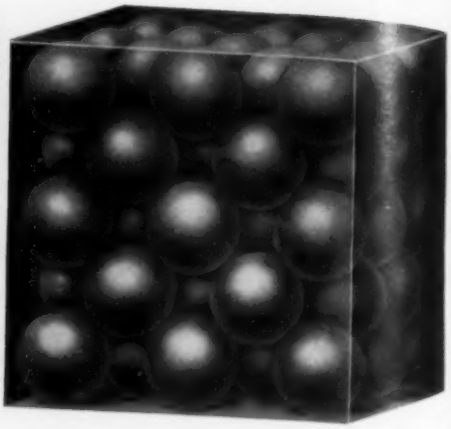


FIG. 3.—THE ARRANGEMENT OF ATOMS IN α-IRON, THE FORM STABLE BELOW 900 DEGREES CENTIGRADE. THE FACES OF THE CUBE SHOWN ARE OF THE CRYSTALLOGRAPHIC FORM {100}.

screw like that of a lathe. Since the hot part of the wire is weak mechanically and reactive chemically, it must be specially protected against mechanical and chemical reagents.

We think we know why these two ways work. In the old method the second operation leaves the metal principally composed of strained crystals which are at every temperature less stable than unstrained crystals. If then a bit of unstrained crystal exists, as is almost certain to be the case, it will at some stage of heating begin to grow by taking over atoms from the strained crystals in its neighborhood and rearranging them to suit its own structure. It can go on growing until it has rearranged all the atoms in the piece or until it meets another growing crystal over which it has no advantage. In this competition similarity of the original grains, the exact degree of over-strain and the rate of heating all affect the probability that one crystal may make a clean sweep.

The new method works because iron has two crystal structures, one stable above about 900° C, the other stable at lower temperatures. The former is called γ-iron and has a face-centered cubic-structure, the latter α-iron, a body-centered cubic structure. One structure starts to change into the other as soon as the temperature of the piece drops below the transformation temperature. If then a crystal of α-iron exists on the cold side of the 900° layer it can grow by taking up atoms as fast as they are supplied to it by γ-crystals on the hot side of the moving boundary. Since the volume within which steady conditions are important is smaller in the new method, it is not surprising that success in it is less dependent upon the purity and previous history of the iron. We find, for instance, that the carbon content does not have to be kept so low and that previous annealing is unnecessary.

Our experimental troubles arise from the mechanical and chemical weakness already mentioned. Small forces steadily applied may cause serious bending and side-slipping in the γ-crystal region, and while the α-crystal often grows right through these imperfections the irregular shape which results makes it impossible to apply the same magnetic and mechanical forces to every part of the

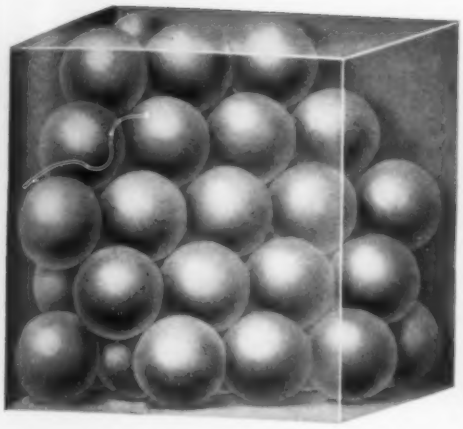


FIG. 4.—ARRANGEMENT OF ATOMS IN γ-IRON ON A PLANE OF THE FORM {111}. THE CUBE SHOWN IN FIGURE 2 HAS BEEN CUT OFF TO EXPOSE SUCH A PLANE

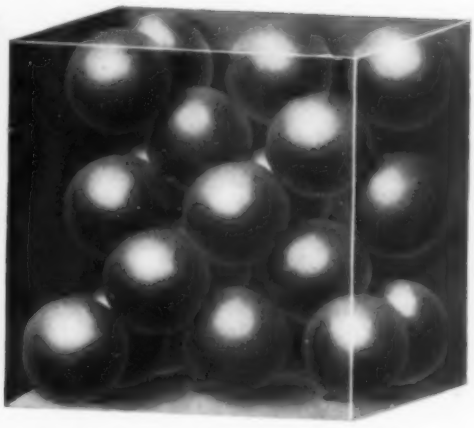


FIG. 5.—ARRANGEMENT OF ATOMS IN α-IRON ON A PLANE OF THE FORM {211}. THE CUBE SHOWN IN FIGURE 3 HAS BEEN CUT OFF TO EXPOSE SUCH A PLANE

α-crystal in the later tests. Sudden jerks and twists have another bad effect. They encourage the appearance of new crystals or at least of faults in crystal structure, such as twinning. The hot iron is readily attacked by oxygen, so that it must be surrounded by some neutral or reducing atmosphere. Hydrogen seems the best of these, but hydrogen readily penetrates hot iron and does not all come out again when the iron cools. Luckily the crystals can be heated in vacuum (below 900° C, of course) to drive out absorbed or locally liberated gases so that the effect these produce upon the magnetic and other properties of the freshly-grown crystals can be estimated.

The contacts for the electrical current which we use for local heating of the wire have also to be designed with care. These contacts must slide along the wire with little friction, must be gas-tight and must also help to keep the ends of the wire cool. A scheme that works well is to use mercury contacts, the mercury filling two cups each with a hole in the bottom just big enough to let the wire pass. The blocks in which the cups are cut are cooled partly by water passed through them and partly by the hydrogen kept flowing gently through the space around the hot part of the wire.

The wires that have passed through the new crystal-growing process are bright and smooth, with no sign upon them to advertise their conversion. A short dip in dilute nitric acid brings out the crystal structure, for the bright planes which best resist the acid are arranged in each crystal parallel to the sides of a cube, and the edges of this cube—the "axes" of the crystal—point in different directions in each. A simple form of goniometer is used to find the directions of these edges which are, of course, normal to the reflecting surfaces left by the etching, and the position of the wire axis with respect to the crystal axes is thus determined. Besides these optical measurements X-ray pictures have been taken in some cases and microphotographs have also been used to check the conclusions arrived at. The X-ray data show that the optical method, while not very accurate, is good enough for inspection purposes, either for judging the success of a crystal-growing ex-

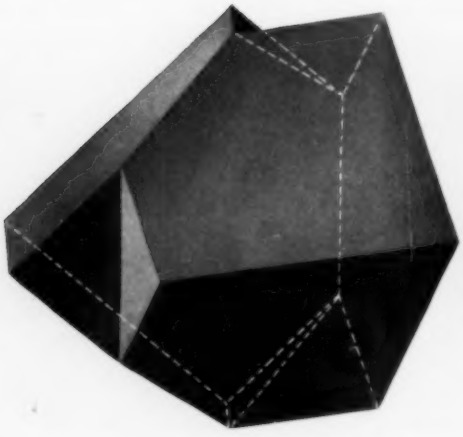


FIG. 6.—THE ARRANGEMENT OF TWINS IN γ-IRON. TWO HALF-CUBES ARE SHOWN, THE COMMON PLANE BEING OF THE FORM {111}.

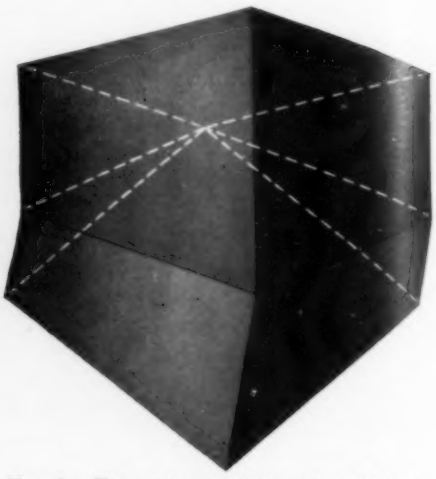


FIG. 7.—THE ARRANGEMENT OF TWINS IN α-IRON. TWO HALF-CUBES ARE SHOWN, THE COMMON PLANE BEING OF THE FORM {211}.

periment or for selecting a crystal to be given more particular study. We are not yet sure that any special orientation of the crystal axes is either preferred or prohibited.

The magnetic behavior both of freshly grown and of "degassed" iron crystals is qualitatively like that of poly-crystalline iron, but the magnetic forces necessary to reach the interesting points of magnetization curves and hysteresis loops are less for the single crystals. This is more easily seen by looking at the diagrams than by reading numerical data. Magnetostriction, the change in dimensions with magnetization, depends in amount and even in sign upon the position of the crystal axes with respect to the wire axis along which the magnetic force always acts and nearly along which the resultant magnetization must also lie. The few magnetostriction curves so far obtained are different for differently oriented crystals. Magnetization curves are not so sensitive to changes in crystal position, and our experiments are not yet complete enough to give safe results on this point.

While spending most effort on the new method we are not neglecting the chance that the old method may give importantly different results. In order to supply comparable samples we are therefore applying Professor Sauveur's method to wires identical in preparation with those used in the progressive process.

When we get a clear picture of how a single crystal of iron goes about changing its state of magnetization and what happens to its dimensions in the process, we expect to have a very fair start toward telling how a few million crystals more or less carefully packed together succeed in doing the same thing and how best to help or to hinder them. Perhaps the constructors of telephone apparatus may even succeed in obtaining in the cores of relays or of coils a new set of desirable magnetic properties.

COMBINATION, UNITY AND PEACE

By Professor EZRA BOWEN

LAFAYETTE COLLEGE

A STATE is an artificial entity, an imaginary person, a common law corporation, a fabricated, planetesimal mass of irresponsible power.

The term state means of course a sovereign state. A state is sovereign or it is no state at all—a province, perhaps, or a confederation or league, but not in world polity an upstanding self-sufficient individual.

The outstanding characteristic of sovereignty is jealousy. Two or more sovereignties may not overlap territorially or in any other way—except as a matter of courtesy or of temporary working agreement. Where two powers find expression in the same area, one or the other of those powers is not sovereign. Fiction such as the co-existence of the sovereignties of Maryland and the United States, of Bavaria and the German Republic, or the Commonwealth of Australia and the British Empire—such legalistic mist from the political tea kettle may be made to fill some backroom of stateseraft, but in the sunlight of reason and the open air of experience it disappears. "The federal troops can not go over Maryland, and they can not go under Maryland; so I guess they will have to go through Maryland"—thus did President Lincoln reply to a remonstrant Baltimore. (Earlier remonstrances had taken the form of stoning a trainload of transient Massachusetts troops.) The "sovereignty" of Maryland or of Saxony or of Ireland is merely a political and legal convenience, a fiction, a stuffed shirt.

Sovereignty is the most jealous of human concepts. Where two sovereignties share the same bed, always one "wakes up dead." Under the Articles of Confederation it was the federal government that perished. Under that thicker blanket, the Constitution, the several states and a new federal government returned to slumber came the nightmare of the Civil War; all writhed in death pains. Next morning the federal government was breathing evenly, but there were thirty-five dead little sovereignties. That was the issue which the Civil War settled. Slavery merely furnished the test case.

The primordial, protozoan state was in all probability the family or clan. The fact that it was at bottom a biologic combination, next an economic combination and only in tertiary consideration a political combination need not prohibit, in a political study, the temporary assumption that this earliest association of human beings was a purely political entity: a number of individuals conjoined to create an imaginary person, the state, to act for them in the exercise of certain surrendered rights. The origin of the state was in *combination*, and its development has followed most conspicuously the path of further and further combination.

Combination meant many things; most of them were, however, far beyond the understanding of primitive man and therefore incapable of furnishing motives to combination; but one thing emerged, sharp, clear and large: Combination meant protection; more combination meant better protection. The family, in its underlying meaning a biologic unit, in its secondary meaning an economic unit, was thirdly a political

unit, a fighting unit, an association to deal with violence and to deal in violence. Biologic and economic bonds resulted from forces working within the group. The political bond came mainly in response to external pressure, a pressing need for protection—the protection that the means to destruction offers against destruction. Violence is colorful, and the quiet pursuit of biologic and economic ends, somewhat dull. No wonder, then, that the war values—or more delicately, the defensive values—of association appeared supreme and became a controlling motive in all political unions.

A clan or tribe may be considered an association of families; a nation, a union of tribes; then nations combine to form great states, and states are welded into empires. Sometimes combination is effected by agreement, sometimes a state gains weight by the simple act of swallowing its neighbor. Each time, security is the motive, explanation, excuse—call it what you will—the chief result, each time, a more terrible and beneficent war-machine: terrible to the foreigner, benign to the citizen.

Combination is very old. Existence in its biologic and economic sense demands it. Combination, with its implication of organization, antedates intelligence; but when intelligence is brought to bear, combination and organization are still for protection, for war. From the dawn of intelligence to the moment that is passing, the world has been organizing—organizing for war: War between families, then war between tribes, war between nations, and war between empires; but within the family, within the tribe, within the nation, within the empire: peace.

Combination, recombination and further combination, with always more terrible wars between the growing units, but more perfect peace within—how long can this principle continue? Hardly until to-morrow. Its explosion point is upon us now; for in unity all combination meets an end. And in this case, unity means universal peace. . . . Clans have combined to form tribes, tribes to form nations, nations to form vast states, states have joined in empires—an age-long process of organizing and reorganizing for internal tranquility and for external violence. Into what can the great states and colossal superstates of the present world, now organized (or organizing) for the next and most terrible of wars—into what can they combine but unity? Peace within and war without; but when all without is all within, there is an end: peace universal.

How will this final unity be achieved? Will some present state gobble her sisters one by one till she swells to world proportions? Or will there be a new state composed of present states united—united by agreement, by covenant or constitution? These two have been the modes of combination in the past. *There is no third.* The first was always swift, sure and usually final; the second, slow and halting—for it must come by conclave and agreement; one or two false steps must precede enduring union: well-meaning gestures like the German Zollverein, the first American Confederation, the League of Nations. Will the universal and final state appear by agreement, or will one present state impose its system upon the world?—will reason be the unifying flux, or can "blood and iron" alone bring unity? This only remains in question.

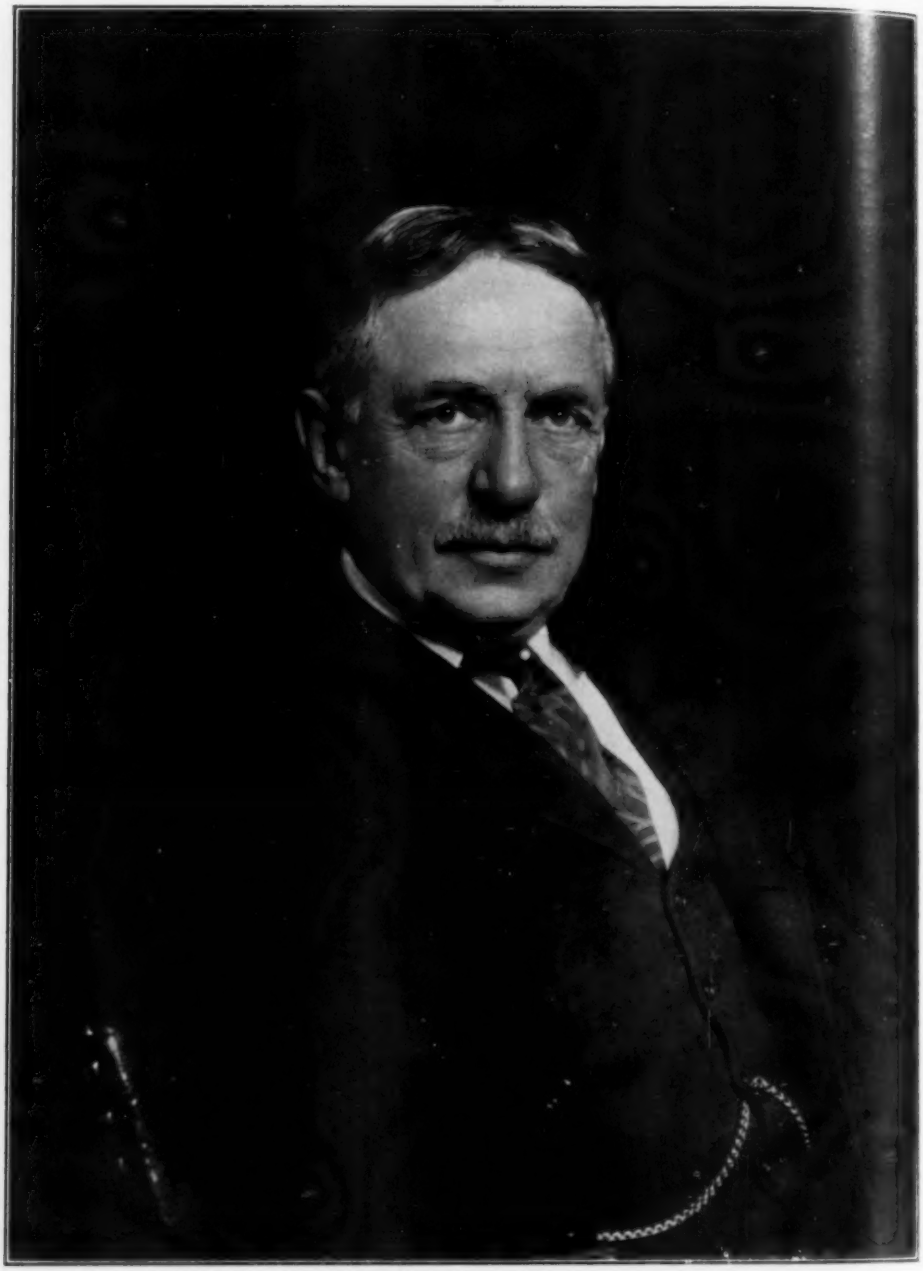
Darius, Alexander, Napoleon and William II may have been the unconscious instruments of a wide-spread will toward world unity through violence. But the most successful of past attempts suggests remoteness and instability in the fulfilment of any present hope. The World's unique attempt at unity through agreement, the League of Nations, though

present in the flesh—or rather, partial skeleton—holds out scant hope to those who would complete this skeleton, clothe it in flesh and embue it with the sovereign spirit. But how often—and how suddenly—the whirling of time visits its revenge upon the sluggish human will.

Combination has always offered great advantage: but always great sacrifice has been demanded. In this final congregation, as in all earlier combinations, but one sovereignty will emerge. There is the rub! We can not give our sovereignty, and keep our sovereignty. The new world organization will be sovereign, or it will be a thin pink peace mist, upon which the rising red sun of war will make a hasty breakfast. Here is the sum of human experience with political consolidation.

The principle of combination—to the end of greater security—has not progressed continuously. There are more sovereign states to-day (1927) than there were ten years ago. Other periods in the world's history have seen temporary increase in the number of independent nations. But from century to century a decrease in number and a corresponding increase in the weight of sovereignties has been constant. Few modern nations are so small that they do not contain several ancient states. To uncover them it is necessary only to turn back a few pages of history, archeology or ethnology. A constant decrease in numbers is, certainly, a trend toward unity; this is our thesis.

Independence, with the constant horror of a violent end, or political combination with the prospect of causing someone else's violent end: this was always the choice. The gentle force of reason often sufficed to bring combination. This time it should certainly prevail. For, although the sacrifice that each combining state must make is just what it has always been—enough of its own power to ensure life to the new super-power—this time the gain is indefinitely greater. Earlier combinations were always offset by counter-combination. A Triple Alliance was formed; it was counter-poised by a Triple Entente; the gain was temporarily or relative. This time, the net prospective gain is absolute, total, final. As ever, each conjoining state must deduct loss of sovereignty from prospective profit. But from that net there need be no deduction—this time, no loss from counter-combination. The end is not merely a greater degree of safety derived from a greater power for violence: the end is world unity and peace.



DR. HENRY FAIRFIELD OSBORN

PRESIDENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY AND RESEARCH PROFESSOR OF ZOOLOGY IN COLUMBIA UNIVERSITY, WHOSE SEVENTIETH BIRTHDAY WAS CELEBRATED ON AUGUST 8. THERE WAS PRESENTED TO HIM BY HIS COLLEAGUES AND FRIENDS A VOLUME CONTAINING NEARLY A THOUSAND SIGNATURES, TOGETHER WITH A CUP. LATER THERE WILL BE A RECEPTION AND THE PRESENTATION OF A FUND FOR RESEARCH WORK.

THE PROGRESS OF SCIENCE

EDITED BY EDWIN E. SLOSSON
Director of Science Service

FLUID FUEL

THE mobility of man is measured by the mobility of the power he employs. Consequently, the efforts of technologists are now directed toward increasing the fluidity of fossil fuel. The finer the particles the more fluid the form. The cheapest and most abundant source of energy is coal but this is solid and deeply embedded in the rocky matrix of the earth's crust. From this matrix the coal has to be torn loose by explosives and then broken into lumps small enough to be shippable and shovelable. Putting fuel into powdered form it can be blown into a furnace on a blast of air. By combining it with hydrogen we can reduce the carbon to a liquid form and by heat convert it into a gaseous state where all the molecules are free and independent. Fuel in this free and fluid form, like gasoline and Diesel oil, has given us the internal combustion engines and made possible the automobile, the airplane and the submarine.

But the atom is not the limit of divisibility, although that is what its name implies. As we now know, it is possible to break up the atom, and its finer fragments, electrons and protons, afford us a still more fluid form of energy, the electrical current. To transport solid coal from the mine to the factory requires a large part of its power. To transport water from the mountain to sea requires no power. It will flow down hill of its own accord if you will only provide it with a sloping channel or an empty pipe. To transport electricity from a point of high potential to a point of low potential requires no power. The current will flow down hill of its own accord if you will only provide it with what is for it an empty pipe, that is, a copper wire. And the electric current will travel far faster than the coal train or the flowing stream. So the efforts of inventors are now concentrated on methods of increasing the mobility of energy by such means as converting coal into a liquid form, or converting its energy into the electrical fluid.

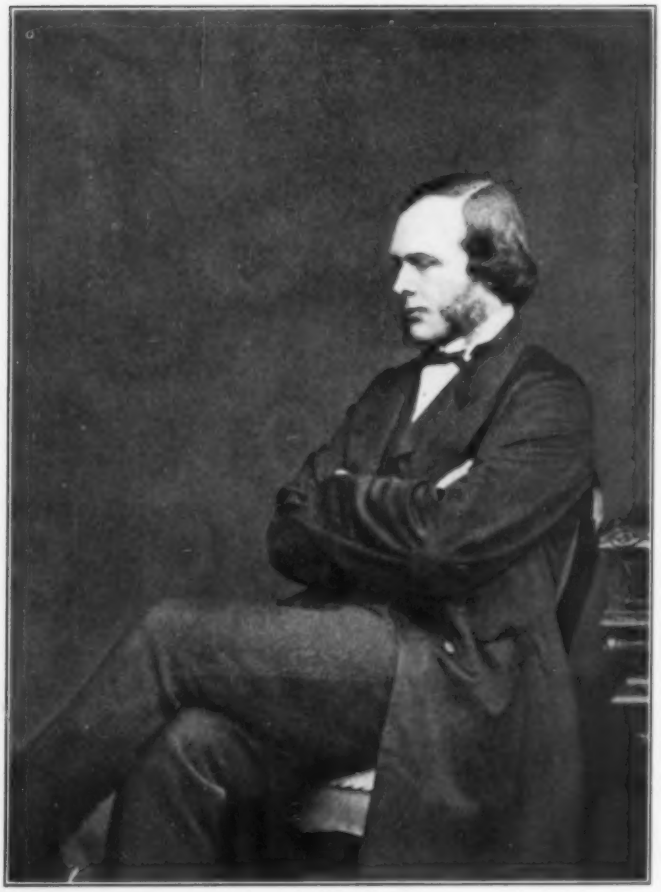
The transmission of power by wire is in actual operation up to two hundred miles and has been carried on experimentally up to a thousand miles. The wireless transmission by ether waves traveling at the rate of 186,284 miles a second is a vision of the future. Since such a speed is virtually instantaneous for all points on the globe the limit of mobility is here attained.

PROTECTION FROM POISON IVY

POISON IVY, the bane of the vacationist's existence, is with us again. Every motor trip, every picnic, every hike through the woods is apt to be followed by a blistered, red, intolerably itching casualty, or at least will have the best edge taken off its pleasure by the nervous anticipation that such ill consequences may follow a few hours after brushing against some seemingly innocent vine or bush. Remedies by the hundreds are recommended by doctors, by druggists, by old-fashioned housewives. Some of them work, some of them just serve to keep the patient in as cheerful a frame of mind as possible until the

LORD LISTER

THE CENTENARY OF WHOSE BIRTH IS BEING CELEBRATED. IN THE PRESENT ISSUE OF THE SCIENTIFIC MONTHLY THERE IS PRINTED THE ADDRESS GIVEN BY LISTER WHEN HE WAS PRESIDENT OF THE BRITISH ASSOCIATION. IT GIVES AN ADMIRABLE ACCOUNT OF HIS CONTRIBUTIONS TO ANTISEPTIC SURGERY AND OF THE RELATION OF RESEARCH IN SCIENCE TO THE PRACTICE OF MEDICINE.



LISTER

AS HE APPEARED AT THE TIME WHEN HE WAS CARRYING ON HIS INVESTIGATIONS OF ANTISEPTIC SURGERY.

afflicted place gets well by itself. The handling of ivy poisoning, and of its kindred ailments oak and sumac poisoning, is still in a more or less chaotic condition.

Scientific order, however, is being brought out of it by the efforts of botanists, chemists and physicians, and now there are a few standard remedies, and what is even better, standard preventives, that anybody can have his corner druggist mix up in a few minutes. There is nothing "patent" or proprietary about them; they are all old familiar chemicals, and they don't cost much.

The best remedy is axiomatically one that destroys the cause of the ailment, and it is for this reason that Dr. James F. Couch, of the U. S. Department of Agriculture, expert on poisonous plants, recommends the use of a solution of permanganate of potash to stop the itching, blistering irritation that follows contact with poison ivy, poison oak or poison sumac. Five per cent. of the compound in water is all the prescription your druggist will need. Bathe the afflicted skin freely with this solution, swabbing

it on with a bit of cotton or soft cloth, and the poison will be oxidized and destroyed. This treatment leaves a brown stain on the skin, which can easily be removed in any one of a number of ways. A one per cent. solution of oxalic acid, Dr. Couch says, is the quickest means. But oxalic acid is a poison, so that if you are afraid of children getting hold of it you may use instead a one per cent. solution of sodium bisulphite, or even just plain soap and water, though the latter is a bit slow in taking off the stain. If the skin has been very much broken by scratching or otherwise and is raw, the oxalic acid will cause a temporary stinging and soap and water is preferable for removing stains from such sensitive surfaces. If the skin is very tender the solution of potassium permanganate may be diluted with water before using.

The permanganate treatment is recommended only as a remedy for poisoning that has already taken place. Persons who know that they are likely to be poisoned may prevent the plant from harming them with a wash devised by Dr. James B. McNair, of the Field Museum, Chicago. This consists of a five per cent. solution of ferric chloride in a fifty-fifty mixture of water and glycerin. This is to be washed on all exposed parts of the skin and allowed to dry there, before going where the dangerous weeds grow. The iron in the chemical combines with the poisonous principle of the ivy and changes it into a harmless, non-poisonous compound.

MUTATIONS CAUSED BY X-RAYS

THE rate at which breeds of animals and plants can be improved will be speeded up over a hundred times if the findings made by Professor H. J. Muller, of the University of Texas, on tiny fruit flies, holds true for other living things. It has been proved in his experiments, carried on at Austin, Texas, during the past nine months, and just reported in *Science*, that in the flies X-rays affect the little particles responsible for heredity in much the same way as a shot-gun fired at a pile of pebbles would affect the pebbles. The hereditary particles become permanently transformed in all sorts of unexpected ways—the changes known as "mutations" are produced in them. Not all of them mutate at once, but here one, there another, in quite a random fashion, and sometimes, too, they are dislodged into new arrangements. Since these hereditary particles, which are known as "genes," are handed down from parent to offspring, and determine the characteristics of the next and later generations, all kinds of new traits are likely to arise among a group of offspring or grand-offspring from parent flies that were treated with X-rays. These new traits are permanent, as they are inherited by succeeding generations.

It has long been known that such "mutations" occasionally happen without X-ray treatment, and so give a chance for the breeder to improve his stock, by breeding from animals that have desirable mutations. In the same way in nature, the "survival of the fittest" mutations is thought to have brought about evolution. But the mutations that happen without X-ray treatment are exceedingly rare and it has never previously been found possible to make them occur oftener. That is why animal and plant improvement has been so slow, and why it has been necessary to raise countless thousands of ordinary individuals for each advantageous mutation that has turned up. Now, if mutations can be produced at will, all this will be changed.

It is true that, even if X-rays can do in cattle and cotton what they do in flies, the kind of mutation that will be produced can not be specified in advance, any more than this could be done in the past. Many different kinds of changes

will be produced, in a hit-or-miss fashion, and the great majority of these will consist of derangements, deformities, and even fatal weaknesses. But this is also true of the mutations that occur naturally. The breeder then has to select from among all these changes the few that happen to be to his advantage, and breed from them only. There is no reason to believe that the number of desirable changes, in comparison with a given number of harmful ones, would be any less after X-rays than naturally. In fact, in the flies, many of the X-ray mutations look just like the natural ones. So the practical effect of the treatment, in producing over a hundred times as many mutations of all kinds in a given number of individuals, would really be to make unnecessary over 99 per cent. of the breeding of ordinary individuals that now has to be carried on before each mutation of a desired type is found.

While it seems a far cry from flies to four-footed beasts, it has always been found in the past that the principles of heredity found in the flies apply also to plants and to higher animals, including man himself. This raises very acutely another question, one that has at times in the past few years been debated among X-ray practitioners—whether, in treating their patients, they are not sometimes producing mutations that may crop up in future generations. If so, some of our medical practices will have to be modified, for there is no doubt that in man, as in flies, most of the mutations produced would be of a detrimental kind.

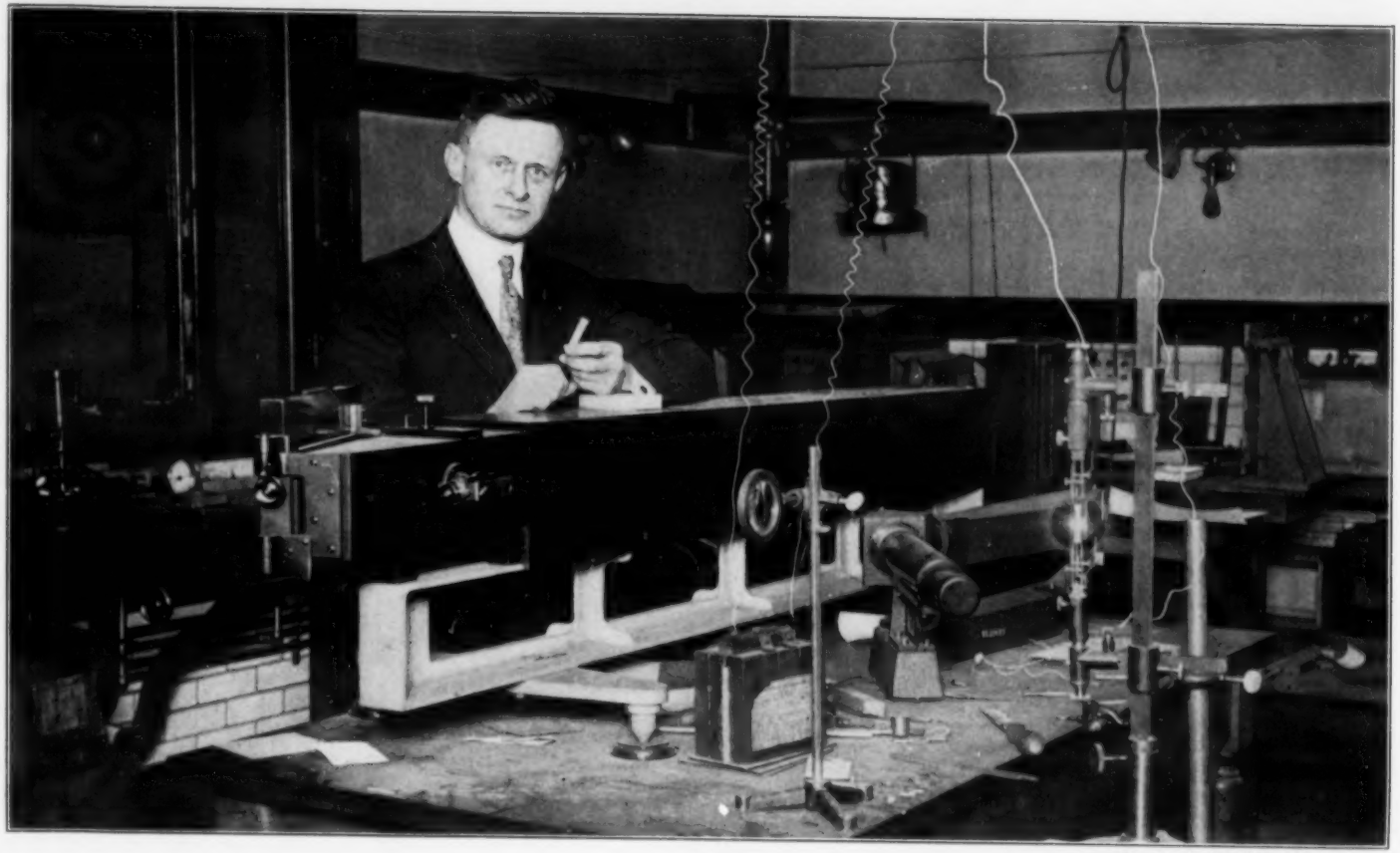
To scientists, the most interesting aspect of the work will probably be the insight which it may give us into the causes of evolution and into the nature of the little genes themselves. In fact, certain conclusions regarding the structure of genes have been drawn from the work that has already been done. These will be presented by Dr. Muller in a technical paper before the International Genetics Congress, to be held in Berlin this September.

HAFNIUM

THE story of the discovery of helium has been told so often that it is commonplace. The story of hafnium is more recent, and probably less familiar, although not less romantic. It begins with the relation between atomic number and frequency of Röntgen rays, discovered in 1913 by Moseley (England), which definitely fixed the number of possible chemical elements between barium and tantalum as 16 (atomic numbers 57 to 72 inclusive). All but two of these had been identified by the time this law was announced—the unknown elements could only be referred to by their atomic numbers 61 and 72.

In 1878 Marignac (Switzerland) separated from erbium a new earth which he called ytterbium. Auer von Welsbach (Austria) in 1905 found that ytterbium was a mixture of two elements; he proposed the names aldebaranium and cassiopeium. Urbain (France) independently made the same discovery and proposed the names neo-ytterbium and lutecium. Later Röntgen-ray investigations indicated that the atomic numbers of these new elements were 70 and 71. It was then conceivable that the hypothetical element 72 might be present in the final mother liquor from which 70 and 71 were obtained, and both Auer von Welsbach and Urbain looked for it. The former did not find it, but the latter thought he did and announced in 1911 the discovery of a new rare earth which he called celtium.

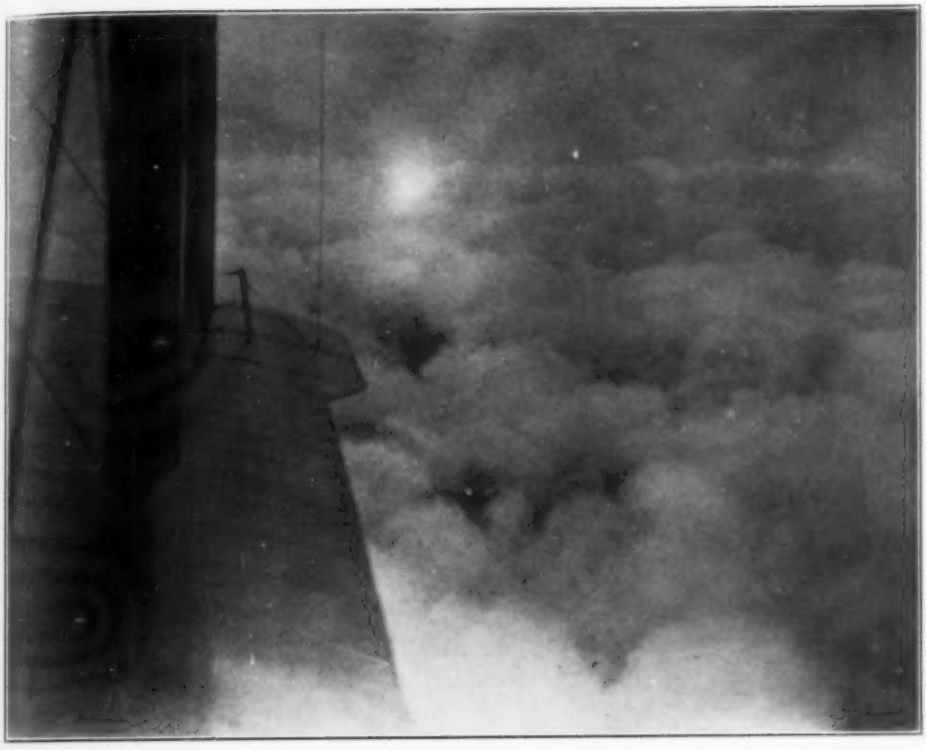
Eleven years later the quantum theory and explanation of the periodic system of chemical elements was sufficiently developed by Bohr (Denmark) to define very sharply the character of element



—*Copyright by Harris & Ewing*

DR. W. F. MEGGERS

OF THE BUREAU OF STANDARDS, ENGAGED IN THE STUDY OF THE SPECTRUM OF HAFNIUM.



THE ECLIPSE OF JUNE 29

A PHOTOGRAPH TAKEN FROM AN AEROPLANE OVER BIRKENHEAD.

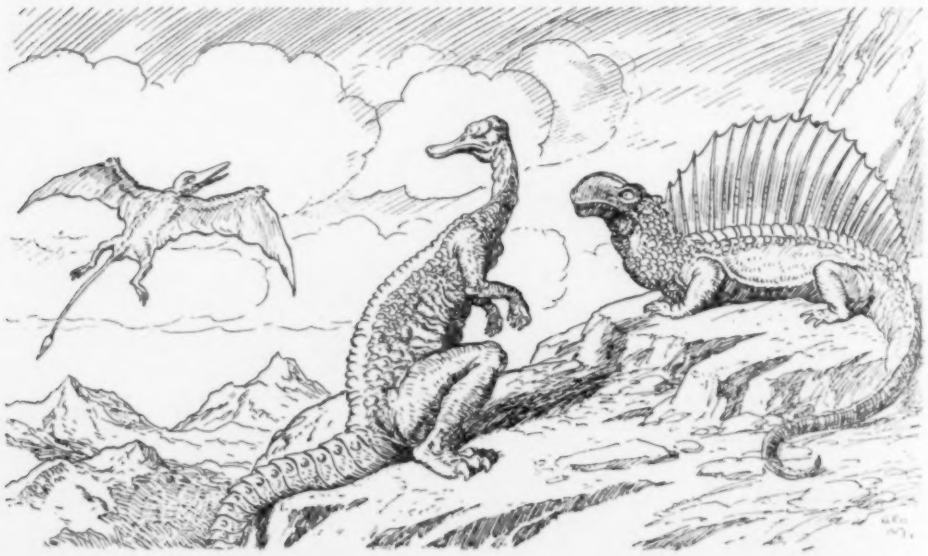
72. Purely theoretical considerations indicated that 72 could not be a rare earth; from the predicted atomic structure it was seen to have a close resemblance to zirconium, the atomic number of which is 40. When a sample of zirconium was carefully tested predicted lines of the Röntgen-ray spectrum of 72 were actually found. After thus identifying the new element, its presence in various zirconium minerals and preparations was detected and it was successfully separated from zirconium by chemical processes. Coster and Hevesy (Denmark) announced the discovery of the true element number 72 in a letter addressed to *Nature* on January 2, 1923. They proposed the name hafnium because it was in Copenhagen (the Latin name of which is Hafnia) in the Institute for Theoretical Physics, directed by Professor Niels Bohr, that the remarkable discovery was made.

It has since been established that all zirconium minerals contain, on the average, several per cent. of hafnium so that the new element is not really a "rare earth" in the literal sense. In fact, it constitutes between 0.0001 and 0.001 per cent. of the earth's crust. In this sense it is of the same order of abundance as lithium, copper, cerium, cobalt, boron and beryllium, and is, therefore, a thousand times more plentiful than silver and ten million times more abundant than gold. Its chemical properties are such that it is separated from zirconium with great difficulty, and without the suggestion from theoretical physics it is doubt-

ful if its presence in zirconium minerals ever would have been suspected.

Small quantities of hafnium have been purified to a very high degree and these have been used to determine the chemical and physical properties of the new element. The atomic weight has been found to be 178.6. In addition to the Röntgen spectrum, 800 lines of the optical spectrum of hafnium have been published by Hansen and Werner (Denmark). Through the generosity of Professors Bohr and Hevesy, two samples of hafnium were presented to the Bureau of Standards for spectroscopic investigations, which are being conducted by Dr. William F. Meggers. With these, the description of the optical spectrum has been confirmed, many new lines have been photographed in the ultra-violet and in the infra-red, and a separation of the lines originating with ionized atoms from those characteristic of neutral atoms has been effected. Comparison of these data with similar descriptions of the zirconium spectra check the statement that all zirconium preparations contain some hafnium, and show that at least one sample of hafnium has been prepared almost entirely free from zirconium. The structure of the hafnium atom, the main features of its spectra, the electron configurations responsible for its spectral terms, are all known to the quantum theory; it only remains to classify the spectrum lines and thus crown the theory with inevitable, complete success.

A PIONEER



—*From Punch*

Very Early Reptile. "Hullo! That's something new. Flying, eh?"

His Friend (patronizingly). "Oh, that's young Archae opteryx, a relation of ours. Rather an amusing idea. Sporting and all that, but of no real utility."